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Lincoln College

THE APPLICATION OF LINEAR PROGRAMMING TO PROBLEMS OF NATIONAL ECONOMIC POLICY IN NEW ZEALAND

by

T. R. O'Malley

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THE AGRICULTURAL ECONOMICS RESEARCH UNIT

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CHAPTER I

INTRODUCTION

1.1 The Reason for Planning

A current belief in the virtue of "private enterprise" and, perhaps, unsavoury visions of the Fascist dictatorships and Communist regimes of the present and recent past, have caused "central economic planning" to be regarded with scepticism and even contempt in the Western world. As this thesis is concerned with the development of a quantitative model which has the potential to be used by a central authority as a guide to planning economic growth, a brief attempt to dispel this notion seems warranted.

W. Arthur Lewis, in the first chapter of "The Principles of Economic Planning"[20], [1] clearly shows that at least some form of central direction is required if an economy is to operate smoothly. An indefatigable faith that the market forces of supply and demand best serve the objectives of society (whatever they are) does not prevent the diseconomies and waste which often occur due to imperfect knowledge of the vagaries of prices, trade cycles, market trends and so on. An overall planning agency which has both knowledge

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[1] Throughout this script numbers in square parentheses correspond to references listed at the end of the volume.

and control of the relevant variables will often be able to foresee and prevent such losses. Of course there are a number of services which, because of the collective way they are consumed, must be centrally organised. Defence, justice and traffic control are obvious examples, but the State's jurisdiction extends to other "matters concerning the public good", and controversy can arise as to how far it should interfere with individual freedom of choice (e.g. liquor laws). In this sphere an economic planning agency is likely to be involved with the regulation of economic activity by licensing or some other form of direct control, and the interference will often be regarded as a violation of basic rights. On the other hand, the distribution of income resulting from a purely market economy will not always be the best from a strictly welfare viewpoint. It is largely a matter of judging which is likely to be the greater cost : the resources used for the time consuming and possibly erroneous calculations of central planners, or the waste caused by the imperfect knowledge of entrepreneurs and the hardship due to inequitable distribution of income.

There is no doubt that certain types of central planning are unacceptable. No administrative body can expect to predict accurately the socially most desirable size and composition of consumption;[1] a price environment must always exist as a test of the worth of a plan; adjustments to the plan should be made when the price-demand mechanism of the market does not quickly adjust to the plan-influenced supply. A general conclusion would be that

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[1] The Pareto condition for welfare maximisation is that the ratio of the marginal utilities of any pair of commodities must be the same for all persons.

direct interference with the market is undesirable (except in emergency situations when temporary direct interference can be imperative), but the concept of guiding market forces within the framework of an overall plan does not conflict with basic rights and is, in fact, necessary for balanced growth and stability in the economy.

1.2 The Theory of Quantitative Economic Policy

Even when there is general assent that interference with the price mechanism is essential, many remain sceptical of economists' ability to quantitatively describe macroeconomic relationships so that practical, effective policies may be prescribed. That there are difficulties is admitted, but this does not mean attempts at quantification are worthless. Often a mathematical representation will predict oscillations in economic variates which far exceed any which would occur in the real world, but only because political intervention prevents them. The policy makers might have seen what is happening without necessarily understanding the underlying causative forces. It is likely that a mathematical model could accurately describe these forces and knowledge of the functions would have suggested less drastic and more effective corrective measures. These sentiments are expressed by Fox, Sengupta and Thorbecke [12] and are possibly best summed up by a remark in their concluding chapter : "Quantification is most important, for without it we can hardly rise above the statement that 'everything affects everything else'."

Jan Tinbergen is one of the pioneers of quantitative economic planning and has written prolifically on many aspects of the subject[36 - 40]. He has suggested a theoretical framework for "economic policy models", the essentials of which are described in Sengupta and Fox [32] as well as in his own writings. Figure 1.1 demonstrates diagrammatically the nature of Tinbergen's concept. The objective of policy is welfare or utility[1] which is a function of a number of variates. These are categorised as "target variables" or variables whose values are endogenous in the economic system (y vector), and "instrument variables" or variables which are exogenous (z vector). The instrument or policy variables together with predetermined or "uncontrollable factors" (u vector) interact in a set of structural relationships (the model M) to give values of the target variables. Also there are "irrelevant variables" (x vector) which are side effects of the economic structure and do not affect the welfare function. The idea of a "policy model" is to reverse the structural relationships so as to calculate values of the instrument variables consistent with particular values of the target variables. When the quantitative relationships have been established the policy economist is charged with the task of setting acceptable levels of the target variables and solving the set of equations for values of the instrument variables, the only variables over which the planner has any control. The acceptability of the targets can be tested against the value of the welfare function. The feasibility of a policy solution is usually ensured by the mathematical relations in the model; factors which limit economic activity such as resource availability or technology should be accounted for as predetermined variables and would be entered in the calculations as data, or maximum and minimum

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[1] Welfare and utility should not be regarded as synonomous. Welfare can be thought of as a weighted sum of the levels of utility achieved by the individuals which, en masse, compose society.

"boundary conditions" may be placed on values of the targets and instruments. A possible mathematical formulation, using linear relationships, of a Tinbergen-type model follows.

Optimise

$$W = a'y + b'z \qquad \text{(welfare function)}$$

such that

$$Ay = Bz + Cu \qquad \text{(model M)}$$

$$y_{min} \leqslant y \leqslant y_{max} \qquad \text{(boundary conditions)}$$

$$z_{min} \leqslant z \leqslant z_{max}$$

where

y is an I x 1 vector of target (endogenous) variables

z is an I x 1 vector of instrument (exogenous) variables

u is a K x 1 vector of uncontrollable (predetermined) variables

a', b' are I x 1 vectors of coefficients

A, B are I x I non-singular matrices of coefficients

C is an I x K matrix of coefficients.

The reduced form of the model M is:

$$y = (A^{-1}B)z + (A^{-1}C)u.$$

The reduced form coefficients of this structure can be estimated using econometric techniques.

$$Bz = Ay - Cu$$

or $$z = (B^{-1}A)y - (B^{-1}C)u$$ [1]

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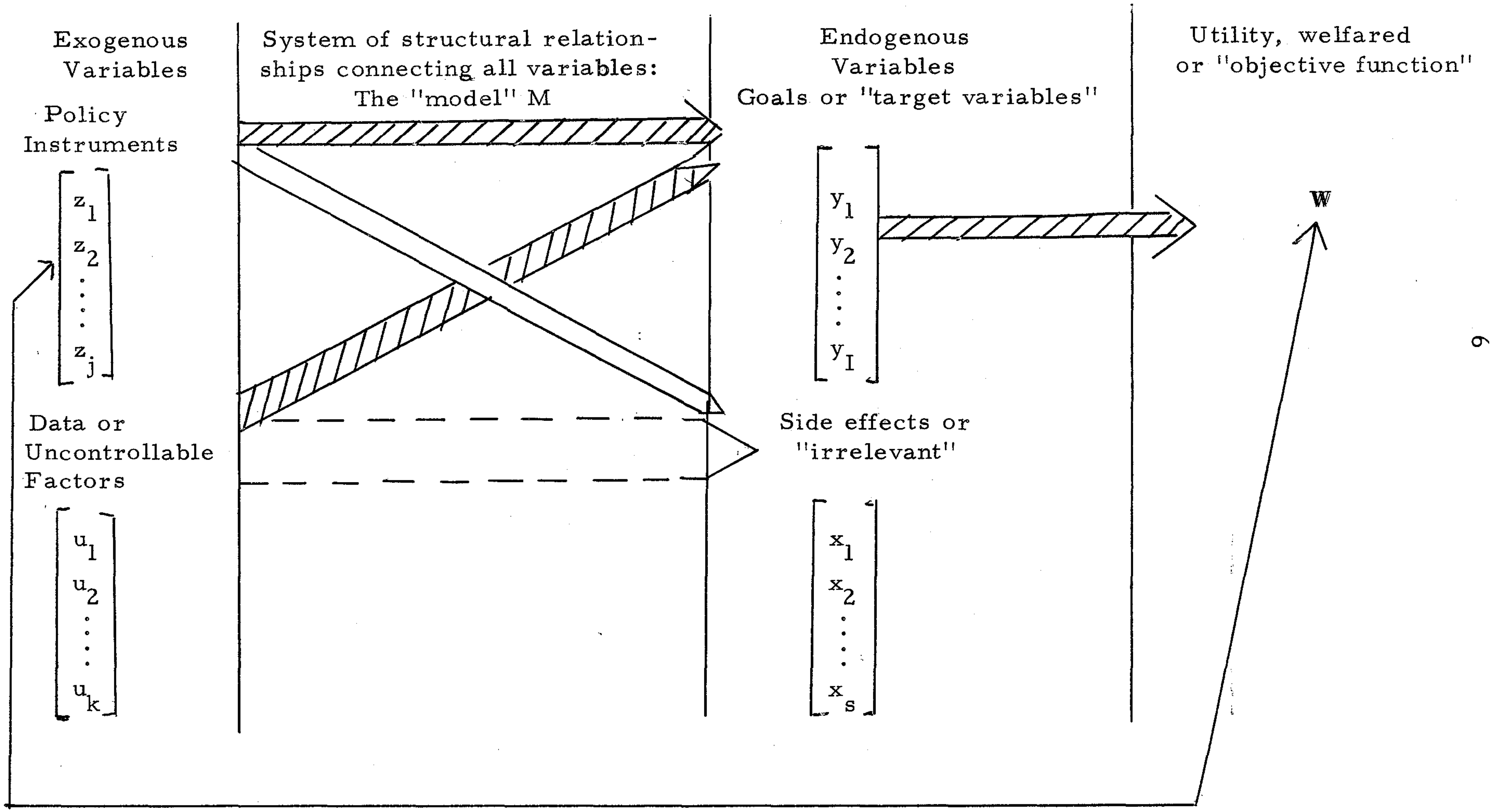
[1] It is not necessary that model M be exactly identified in order to solve the policy problem; the reduced form coefficients are sufficient since $B^{-1}A = (A^{-1}B)^{-1}$

and $B^{-1}C = (A^{-1}B)^{-1}A^{-1}C$

FIGURE 1.1

<u>Tinbergen-Type Policy Model</u>



Copied from Chapter 1 of Sengupta & Fox "Optimisation Techniques in Quantitative Economic Models".

The welfare function is not directly included in the policy calculation of this system, a situation which need not occur when using the Tinbergen principles. This would be classified as a "fixed target" policy model because the values of the target variables are decided before the equations are solved. The number of instrument variables must equal the number of target variables and the matrix B must be square and non-singular so that the values of the vector z can be calculated using the estimated reduced farm coefficients.[1] However, it is possible to devise "flexible target" models in which the welfare function is optimised within the calculating routine. The numbers of targets and instruments need not be equal in these models as is the case when linear programming is the mathematical tool on which the system is based. In this instance the number of policy variables in the optimum solution will equal the number of target variables although the number of instruments or policy choices specified in the original model formulation will usually be greater.

The use of computational apparatus like that just described is only part of the role of policy economics. Before a model can be assembled considerable thought and research must go into the selection and classification of variables. Also, when the policy solution has been achieved it has to be interpreted with respect to its feasibility, the degree of uncertainty, and the measures which should be implemented to bring the plan into reality.

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[1] The matrix A is required to be square and non-singular for equational consistency as the number of structural relations must equal the number of endogenous variables.

Models which have been used for quantitative planning fall into two main categories : those whose functional relationships are estimated using econometric techniques, and those whose relationships are based on input-output coefficients. Traditional input-output models are usually projection routines of a fixed target nature, but recently considerable progress has been made in the development of flexible target optimisation models in which mathematical programming techniques are used with modified input-output data.

1.3 The Aims of Policy

Occasional reference has been made to welfare functions, objective functions, the goals of society and the like, but no indication has been given of the appropriate mathematical expression of these ideas. Indeed, this is one of the weaker aspects of applied economic science; the measurement of social values is an area in which economists often resort to subjective judgments and rash generalisations. Nevertheless, there are a number of easily quantified concepts which are likely to have considerable bearing on total welfare. The following list covers most of them, although difficulty arises as to the weight which should be placed on each concept:

(a) The size of per capita income.

(b) The level of employment.

(c) Stability of prices.

(d) Equilibrium in the balance of payments.

(e) Equitability of income distribution.

(f) The lack of disparities in the prosperity and growth of different regions within the economy.

(g) Diversification in the economy.

(h) The "wealth" of the economy.

Often these goals will conflict and one has to be sacrificed for the sake of another, or some form of compromise has to be found. It must be remembered, however, that these aggregates are not likely to account for social costs such as pollution caused by large scale industrialisation, the lack of recreational and cultural facilities due to rapid suburban expansion, or the spoiling of scenic beauty by intensive agricultural practices. These problems are ignored in this study, as they have been elsewhere, not because they are small in importance but because of the rather modest aims of the exercise. This study is more concerned with the understanding and implications of sectoral interaction in the New Zealand economy than with prescribing a hard and fast optimal economic structure; it is principally involved with the "model M" part of the Tinbergen scheme. If more appropriate objective functions are specified in the future it should be possible to modify the model to accommodate them.

1.4 Research at Lincoln on Models for Indicative Planning

The Agricultural Economics Research Unit at Lincoln College has been following for some time a research programme entitled "Studies in the Structural Development of the New Zealand Economy". In New Zealand the size of the agricultural and agricultural produce processing sectors relative to the rest of the economy is such that changes in expectations and activity within these sectors have a considerable influence on the economic climate in which other sectors exist. Input-output analysis is a useful empirical tool for examining interdependent situations of this kind. Consequently, the work at Lincoln has involved the use of an input-output model to project the structure[1] of the economy in a target year, given an acceptable level of consumption for that year and assumptions about the values of vital parameters in the model. Parameters affecting expectations in the agricultural sectors such as the terms of trade for exports of farm products are of particular interest.

The model has initially been based on sixteen sectors and the nature of the projecting routine, the assumptions used, and the results achieved have been presented by Philpott and Ross [29], and Ross and Philpott [30]. The projecting routine is an iterative one, and is conveniently described diagrammatically as in Figure 1.2. The key to the symbols in the diagram is:

A is a matrix of current input-output coefficients.

B is a matrix of capital input-output coefficients (includes capital import coefficients).

C is a vector of target changes in consumption plus government expenditure.

E is a vector of changes in exports by sectors.

K is a vector of capital formation by sectors.

M is a vector of current import coefficients.

D is a vector of capital-output ratios.

A set of values for the consumption[2] vector C is decided on by the planning body. The inverse of the input-output matrix A

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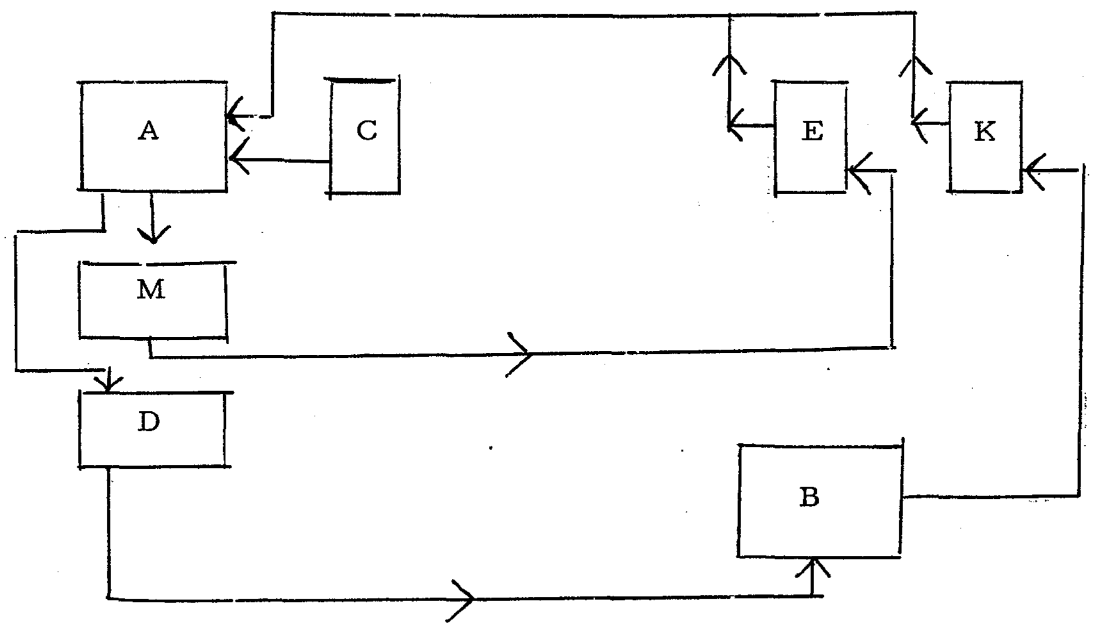
[1] "Structure" in this context refers to: the relative level of output of each of the sectors of the model, the relative level of exports from each sector, the relative level of investment by each sector, and the relative level of importing of current and capital goods by each sector.

[2] "Consumption" will usually mean "consumption plus government expenditure".

FIGURE 1.2

Illustration of Iterative Calculations of Lincoln Projection Model



Key to symbols contained in text.

is used to calculate changes in the level of output in each sector required by the increase in final demand. It is assumed that the economy has previously been operating at full capacity in all sectors so that the capital required for this extra production must be formed within the system. The investment required is calculated with the vector of capital-output ratios D, and the matrix of capital input-output coefficients B is used to calculate further increases in output (the vector K) and imports demanded by investment flows. Imports, needed for the increases in current output, are calculated using the vector of import coefficients M and the total import increases from this "first round" of computations determine increases in the levels of exports (the vector E) so that balance of payments equilibrium will be maintained. The increases in output necessary to satisfy the importing and investment requirements of the "first round" of calculations are the basis of a "second round" and so on until all the flows in the model are balanced. The feasibility of the resulting structure can be tested by calculating labour requirements (or the requirements of any other limiting primary resource) using labour productivity coefficients and comparing the total labour required with the projected availability of labour in the target year. A number of modifications have been incorporated to augment this basic procedure. These include : an allowance for private capital inflow so that total exports equal imports minus the capital inflow; the prescription of a certain amount of import substitution by lowering import coefficients by a given percentage and adding the differences to the coefficients for manufactured requirements; the inclusion of "autonomous investment" to account for investment which cannot be handled by simple capital-output ratios such as government investment in housing and roads.

The compilation of the data for the sixteen sector model is described in Ross and Philpott [31]. The input-output transactions matrix is an aggregation of the inter-industry statistics published by the New Zealand Department of Statistics for 1959-60 [25], which has been updated to 1964-65 using a technique known as R.A.S. The calculation of the capital input-output matrix is described in Francis [13].[1]

The Lincoln model was used by the Targets Committee of the National Development Conference, 1967 [35] to calculate a set of structural targets to hand on to the Steering Committee [34] whose task it is to formulate measures so that the targets might be realised. The term "indicative planning" has been used in the context of this work as the mathematical solution does not quantitatively define policy solutions, but it indicates which sectors require special attention and provides guidelines to the level of activity which should be induced in all sectors.

1.5 The Aims of the Present Study

This study is part of the Lincoln interindustry research programme. Using the same basic interindustry data the task will be to determine the maximum amount of consumption which can be achieved in the target year. Rather than choosing a vector of

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[1] The coefficients presented by T. W. Francis are not exactly the same as those used for the final projections. Among other things the sector classification is slightly different to that used in the other Lincoln work. However, the methodology is the same as that used for the calculation of the coefficients actually used. See Appendix I for a definition of the sixteen sectors.

consumption targets and using the interindustry relationships to compute a structure which will be the basis for economic policy, the aim is to use linear programming to calculate the structure which will give the greatest level of consumption that the availability of resources will allow. Not only will this method serve as a useful comparison with earlier work, but the linear programming technique gives greater flexibility to the model builder than the traditional Leontief input-output system. In particular the Leontief assumption that each sector produces one, distinct, homogeneous commodity can be relaxed. Thus it is possible to have each of two activities producing the same commodity so that the system can choose between alternative sources of supply.[1] It is also possible to make allowance for diminishing returns by specifying maximum levels for activities so that more of the same commodity can be produced only by an activity which has a larger requirement of scarce inputs.

The scope of this study will be restricted mainly to maximising consumption so that the linear programming solution can be compared with the earlier projections, and there will be only a limited exposition of the ways in which choice can be introduced into an interindustry model. However, it is hoped that the way will be made clear for the formulation of more adventurous programming models of the New Zealand economy.

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[1] Where choice is involved it is usual to refer to "activities" rather than "sectors" or "industries". Different activities producing the same commodity may or may not be part of the same sector in the traditional sense. A full account of the modification of Leontief models using linear programming is given in Chenery and Clark, [8], Chapter 4.

CHAPTER II

THE TREATMENT OF IMPORTS IN INTERINDUSTRY MODELS

2.1 Imports and the New Zealand Economy

The New Zealand economy is unusual among the higher per capita income economies because of its high level of dependence on foreign trade - especially on foreign trade in agricultural products. An illustration of this is given in Table 2.1 which displays the total value of exports and the value of exports of food and agricultural products as percentages of gross national product for a selection of the Western nations in 1966. Iceland is the only country with a higher proportion of exports of food and agricultural products than New Zealand; Denmark and Ireland are only a little lower but both of these are close to the heavily populated European continent, and in the case of Ireland a rather low per capita income is supported. New Zealand is also one of the countries which has a high dependence on total exports, but its unusual position is largely due to the fact that agricultural exports make up 90 per cent of total exports. This situation has come about because of the general paucity of mineral resources on which to base heavy industries so that high living standards have depended on large quantities of imported capital equipment and a very efficient pastoral farming industry has evolved as a means of providing the overseas finance to sustain a high level of importing.

TABLE 2.1

Relative Importance of Export Earnings with Respect to G.N.P.

	G.N.P.	Population	GNP/head	Total Exported Merchandise		Exports, food & agric. products		Food exports as prop'n of total exports
	($US. mn.)	(mn.)	($US.)	($US. mn)	(%)	($US. mn)	(%)	(%)
Australia	24,930	11.541	2,160	2949.6	11.8	2130.0	8.4	71
Canada	53,025	20.050	2,645	9582.4	18.1	2049.9	3.9	22
Denmark	11,119	4.797	2,318	2401.9	21.6	1287.1	11.6	54
France	101,070	49.400	2,046	10886.2	10.8	2025.3	2.0	19
Germany	120,267	57.485	2,092	20134.1	16.7	632.9	0.5	3
Iceland	488	.196	2,490	140.7	28.8	135.8	27.8	97
Ireland	2,919	2.884	1,012	681.6	23.4	406.1	13.9	59
New Zealand	5,453	2.676	2,037	1066.5	19.6	964.6	17.7	90
South Africa	11,906	18.298	651[1]	1684.0	14.1	602.2	5.1	36
United Kingdom	104,944	54.744	1,917	14118.2	13.5	1128.9	1.1	8
United States	756,500	196.920	3,842	29899.0	4.0	7125.0	0.9	29

[1] Calculated on basis of total population rather than white population.

Sources: U.N. Monthly Bulletin of Statistics, May 1968; F.A.O. Trade Year Book, 1968.

The precarious nature of international markets for agricultural products has meant that there has always been pressure for the establishment of import substitution industries in New Zealand. The depression of the 1930s aroused a feeling that the country would be better off if it was more self sufficient. This was one of the driving forces behind the comprehensive system of import controls, first introduced by the Savage Government in 1938, which still exists. It would be desirable, therefore, in a study such as this to examine quantitatively the consequences of different policies of import substitution, and, if possible, to determine the optimum level of importing for each import category - particularly for those imports which are in direct competition with the output of home based industries. Of course it might be necessary to impose limits on the level of importing of some commodities to avoid severe hardship within the labour force of some protected industries. The optimum structure should also allow for risk due to the instability of prices for agricultural exports. Some kind of stochastic programming would be most suitable for this, but for this study it was decided to consider the economic structure for a range of foreign exchange earning coefficients for primary products.[1] The likelihood of diminishing marginal returns for exports, or even specific quota limits for some products, should also be allowed for. This is readily achieved within a linear programming framework if the price elasticities of demand for exports or the quota limits are known.[2]

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[1] A description of the use of random elements in economic policy programming models is given in Fox, Sengupta & Thorbecke [12], Chapter 9.

[2] See footnote on page 42 , Chapter III.

2.2 Methods of Representing Imports in Input-Output Models

If imports are to be meaningfully handled so as to probe some of the questions which have just been raised, it is necessary to understand the various ways they can be represented in an input-output framework. Firstly, the distinction should be made between imports which compete (or have the potential to compete) with the product of domestic industries, and imports which do not face local competition. These will be referred to as "competitive imports" and "non-competitive imports" respectively. Non competitive imports are raw materials or produced goods which, for technical reasons, it is not practicable to mine or manufacture locally. It is usual for these to be treated as lump inputs into the industries or final demand categories using them. Thus the input-output model will have an equation based on the assumption that there are technical coefficients which account for the requirements of non-competitive imports for each industry.

$$NCM = \sum_{i}^{n} f_i X_i + f_y Y \qquad \ldots. \ (2.1)$$

where

NCM = total value of non-competitive imports;

X_i = value of output from industry i ;

f_i = requirements of non-competitive imports per unit of output from industry i ;

Y = value of final demand ;

f_y = imports of non-competitive final goods per unit of final demand.

The assumption of fixed coefficients is usual in input-output models and if it is accepted there is no reason to categorise non-competitive imports; it is the <u>level</u> rather than the physical composition which is of consequence to economic analysis.

With respect to competitive imports, there are decisions to be made by (or for) each sector and each category of final demand regarding the choice between imported inputs and locally produced inputs. An analysis of competitive imports in categories corresponding to the commodities produced by the sectors of the model would be appropriate to an investigation into the economics of these decisions.

2.3 Cameron's Methods

Burgess Cameron [4] has indicated three ways competitive imports can be incorporated into an input-output model.

(1) The first method has a separate row for competitive imports in the model. Competitive imports need to be classified by commodities so that there is a one to one correspondence between the import commodity classifications and the sector commodity classifications. Imports of commodity i are treated as a primary input to sector i which may be thought of as being "resold" to the sectors actually using the imports. The inter-industry coefficients in this model should represent the unit requirements for commodities regardless of their origin (i.e. imported or locally produced); they might be called "true technical coefficients".

$$X_i = \sum_j^n a'_{ij} X_j + Y_i \quad ; \quad i = 1,2....n \qquad .... (2.2)$$

$$TCM = \sum_i^n M_i = \sum_i m_i X_i \qquad .... (2.3)$$

where

a'_{ij} = requirement for commodity i regardless of origin per unit of output by industry j ;

Y_i = value of commodity i required for final demand (regardless of origin).

TCM = total value of competitive imports.

M_i = value of competitive imports of commodity i ;

m_i = import coefficient for commodity i.[1]

X_i as previously defined.

(2) In the second method competitive imports are disaggregated by use as well as by commodity. That is, each of the interindustry coefficients of the first method becomes two coefficients : one is the requirement of locally produced input per unit of output; the other is the requirement of imported input per unit of output. The competing imports row is not needed in this case.

$$X_i^D = \sum_j^n a_{ij} X_j^D + Y_i^D ; \qquad i=1,2\ldots n \qquad \ldots.(2.4)$$

$$M_i = \sum_j^n m_{ij} X_j^D + Y_i^M ; \qquad i=1,2\ldots n \qquad \ldots.(2.5)$$

where

X_i^D = value of home produced output from sector i ;

a_{ij} = requirement of home produced input per unit of output from sector j.[2]

---

[1] If m_i is calculated from a transactions matrix as is usually the case in input-output studies (i.e. $m_i = M_i / X_i$), it implies that imports have a constant share of the market for commodity i; market share

$$= \frac{m_i}{1 + m_i} .$$

[2] The coefficients a_{ij} and m_{ij} relate to the value of domestic output, whereas the coefficients a'_{ij} from the first method relate to total use (the value of domestic output plus the value of imports), i.e.

$X_i = X_i^D + M_i$.

Y_i^D = value of final demand for home produced i ;

m_{ij} = requirement of imported i per unit of output from sector j ;

Y_i^M = value of final demand for imported i ;

M_i, X_i as previously defined.

(3) No attempt is made to classify competitive imports by commodity in the third method, but they are classified according to the industries for which they are inputs. The competitive import coefficient for industry i is the per unit requirement of imported inputs (which could have been produced within the economy). For industry j it is the sum of all the competitive import input coefficients as described in (2) above. As in Cameron's first method there is one equation in the model to account for competitive imports, but the groupings are according to the sectors which use the imports rather than the commodities imported.

$$X_i^D = \sum_j^n a'_{ij} X_j^D + Y_i^D \; ; \qquad i=1 \ldots n \qquad \ldots .(2.6)$$

$$TCM = \sum_i^n (M'_i + Y_i^M) = \sum_i^n m'_i X_i^D + Y^M \qquad \ldots .(2.7)$$

where

M'_i = value of inputs of competitive imports into industry i ;

m'_i = requirement of inputs of competitive imports per unit[1] of output from industry j;

1

$$m'_j = \frac{\sum_i^n m_{ij} X_j^D}{X_j^D} = \sum_i^n m_{ij}$$

$$m_i = \frac{\sum_j^n m_{ij} X_j^D + Y_i^M}{X_i}$$

$$Y^M = \sum_{i}^{n} Y_i^M ;$$

X_i^D, TCM, a'_{ij}, Y_i^D, Y_i^M as defined previously.

Cameron points out the worth of his second method (2) because of its greater detail, but concedes that the necessary data is not usually available without a large scale prior investigation. Consequently, he suggests a data economising version of method (2) in which competing imports of commodity i are divided into:

(a) Imports directly satisfying final demand for i.

(b) Imports of commodity i purchased by industry i.

(c) Imports of commodity i purchased by the other industries.

The main justification for this classification is that the physical differences between these groupings are likely to be matched by differences in import coefficients. Cameron [3] used this method to estimate import substitution by sectors of the Australian economy between 1953/54 and 1957/58.

A set of simplified numerical illustrations of Cameron's four approaches is given in Tables 2.2 to 2.6. It will be noticed that the overall total in Tables 2.4 and 2.5 is less than the totals for the other illustrations. This is indicative of the comment in footnote 2, page 20; the competitive imports used are counted only as primary inputs in each of these tables - the flows are not included as intermediate input-output transactions. In Tables 2.2, 2.3 and 2.6, competitive imports are actually counted twice : once as primary inputs and once as interindustry transactions. Hence the difference between the two totals (2300 - 1975 = 325) is equal to the level of competitive importing.

TABLE 2.2

Basic Data for Three Industry Illustration

(Total levels of commodity available regardless of origin)

	Steel Mfg.	Parts Mfg.	Car Mfg.	Final Demand	Total
Steel	50	150	50	-	250
Parts	-	50	300	-	350
Cars	-	-	200	750	950
Primary Inputs					
Imports	100	125	200	-	425
Factor Inputs	100	25	200	-	325
	250	350	950	750	2300

TABLE 2.3

Cameron Method 1.

	Steel Mfg.	Car Parts Mfg.	Car Mfg.	Final Demand	Total
Steel	50	150	50		250
Parts	-	50	300		350
Cars	-	-	200	750	950
Primary Inputs					
Non Comp. Imports	25	25	50		100
Competitive Imports	75	100	150		325
Factor Inputs	100	25	200		325
Total	250	350	950	750	2300
Comp. import coefficient (m_i)	$\frac{75}{250}$	$\frac{100}{350}$	$\frac{150}{950}$	-	

TABLE 2.4

Cameron Method 2

		Steel Mfg.	Parts Mfg.	Car Mfg.	Final Demand	Total
Steel	D	50	100	25		175
	M		50	25		75
Parts	D		25	225		250
	M		25	75		100
Cars	D			175	625	800
	M			25	125	150
Primary Inputs						
Non Comp. Imports		25	25	50		100
Factor Inputs		100	25	200		325
Total		175	250	800	750	1975
Agg. Comp. Import Coefficient		-	$\frac{75}{250}$	$\frac{125}{800}$	$\frac{125}{750}$	

TABLE 2.5

Cameron Method 3

	Steel Mfg.	Parts Mfg.	Car Mfg.	Final Demand	Total
Steel	50	100	25		175
Parts		25	225		250
Cars			175	625	800
Primary Inputs					
Non Comp. Imports	25	25	50		100
Comp. Imports		75	125	125	325
Factor Inputs	100	25	200		325
Total	175	250	800	750	1975
Comp. import coeff. (m_i')	-	$\frac{75}{250}$	$\frac{125}{800}$	$\frac{175}{750}$	

TABLE 2.6

Cameron Method 4

	Steel Mfg.	Parts Mfg.	Car Mfg.	Final Demand	Total
Steel	50	150	50		250
Parts		50	300		350
Cars			200	750	950
Primary Inputs					
Non Comp. Imports	25	25	50		100
Comp. imports used within industry		25	25		50
Comp. imports used by other industries	75	75			150
Comp. imports used by final demand			125		125
Factor Inputs	100	25	200		325
Total	250	350	950	750	2300
Agg. comp. import coeff.	$\frac{75}{250}$	$\frac{100}{350}$	$\frac{150}{950}$	-	

2.4 Matuzewski, Pitts and Sawyer Models

Matuzewski, Pitts and Sawyer [22] have compared the ma mathematical properties of three models which make different assumptions about the relationships of competitive imports to the economy. In all these models imports are classified by commodity and are therefore similar to the first two Burgess Cameron methods outlined above.

(1) The first model is a completely disaggregated (double-celled) approach as in Cameron's second method.

$$X_i^D = \sum_j^n a_{ij} X_j^D + Y_i^D \; ; \qquad i=1,2....n \qquad ....(2.8)$$

$$M_i = \sum_j^n m_{ij} X_j^D + Y_i^M \; ; \qquad i=1,2....n \qquad ....(2.9)$$

It is pointed out that this system allows different industries to have different propensities to use the same imported input ($m_{ij} \neq m_{kj}$, $i \neq k$), but it does not allow for substitution between imported and domestic inputs since m_{ij} and a_{ij} are all fixed coefficients and bear a constant relation to one another

$$\left(\frac{a_{ij}}{m_{ij}} = \text{constant} \right).$$

(2) The second model corresponds to Cameron's first method.

$$X_i^D = \sum_j^n (a_{ij} + m_{ij}) X_j^D + M_i + Y_i \; ; \quad i=1,2...n \qquad ....(2.10)$$

$$M_i = m_i X_i^D \; ; \qquad i=1,2....n \qquad ....(2.11)^1$$

[1] The joint coefficient $a_{ij} + m_{ij}$ corresponds to a'_{ij} as defined earlier. In the examples described earlier $a'_{ij} \neq a_{ij} + m_{ij}$ as it was related to total use of commodity j rather than total domestic output. In the current example $a'_{ij} = a_{ij} + m_{ij}$ as all coefficients relate to domestic output.

where $Y_i = Y_i^D + Y_i^M$

All other symbols as defined in Section 2.3.

In this case substitution between domestic and imported inputs is possible, but it is specified that total imports of a particular commodity have a constant share of the market for that commodity.

(3) In the third model competitive imports are exogenous.

$$X_i^D = \sum_j^n (a_{ij} + m_{ij})X_i^D + Y_i - M_i \; ; \; i=1,2\ldots n \qquad \ldots.(2.12)$$

$$M_i = M_i \qquad i=1,2\ldots n \qquad \ldots.(2.13)$$

The values of the M_i have to be determined from an independent investigation.

Using a 42 industry input-output transactions table of the Canadian economy for 1949, as well as a table of the flows of competitive imports (cross-classified by the same 42 industries), inverse matrices were calculated for each of the three models just described. A final demand vector for 1956 was then used to calculate industry output levels for each model, and levels of competitive imports for the first two models. Each set of projections was compared with direct estimates of the actual outputs and the actual competitive inputs so that the relative accuracy of the models could be evaluated. The first model performed best, although only marginally better than the second.

2.5 Imports and Linear Programming

Both of the studies just reviewed apply to input-output analysis as it is used for projection of the sectoral structure of the economy rather than calculation of the optimum structure. Nevertheless, a general conclusion would be that the "double-celled" treatment, in which there are separate coefficients for locally produced and imported inputs of the same commodity, gives the best picture of the economy at any one time. It has been pointed out, however, that there is a degree of inflexibility in that substitution between local goods and competitive imports is not allowed for. But if sufficient information is available for a model of this type to be formed, the true technological coefficients can be calculated (a'_{ij} rather than a_{ij}, m_{ij}). These provide the best basis for a programming model which, hopefully, should be able to make the optimal "decision" regarding import substitution. Table 2.7 illustrates how this might be achieved for a three sector economy. Any activity requiring commodity 1, for example, has the choice of using the domestic production activity or the importing activity for commodity 1 (these are the only activities in the model with a negative coefficient in Row 1 and are therefore the only activities which are a source of supply of commodity 1). The only input for the importing option is a unit of foreign exchange, whereas the domestic activity requires other inputs but has a lower requirement of foreign exchange. The programming routine will choose between the two so that the marginal revenue (marginal addition to the objective function) is greater than or equal to the marginal cost for each activity.

2.6 Assessment of Data Available for New Zealand

In the Lincoln input-output projection model, which is the base for this study, no distinction is made between competitive and non-competitive imports. Nor is any distinction made between different imported commodities. There is simply an import coefficient for each sector and final demand category which represents

TABLE 2.7

Sample Layout for Choice Between Local Production and Competitive Imports

	Domestic Production Activities			Importing Activities		
	Commodity 1	Commodity 2	Commodity 3	Commodity 1	Commodity 2	Commodity 3
Row 1	$a'_{11} - 1$	a'_{12}	a'_{13}	-1		
Row 2	a'_{21}	$a'_{22} - 1$	a'_{23}		-1	
Row 3	a'_{31}	a'_{32}	$a'_{33} - 1$			-1
Foreign exchange	m_1	m_2	m_3	$+1$	$+1$	$+1$

a'_{ij}, m_i as defined in Sec. 2.3.

the proportion of inputs which are imported. The Department of Statistics data on which the Lincoln model is based gives imports of 44 sectors in 73 commodity categories. It also gives a list of imported commodities "treated as competing with domestic production delivered to intermediate demand".[1] However, it would be a considerable task to classify the 73 commodity groupings into commodities corresponding to the output of the 44 sectors because of difficulties of definition; a large amount of overlapping between the 73 commodity classifications and the 44 (or 16) categories means that this would not be a simple aggregation. In addition to this there is a problem concerning the degree of protection afforded to some industries; the published figures refer to the existing level of competitive imports rather than the potential level if physical quotas were removed. For the sake of what was considered to be the more urgent need, the development of an optimisation model of the New Zealand economy, a more arbitrary approach than that suggested in the last section for the treatment of imports was adopted.

Most competitive imports - certainly those which are interesting from the import substitution aspect - compete with commodities which are products of the "Other Manufacturing" sector of the Lincoln model. Alternative activities could be offered for each sector or final demand activity in which the coefficient in the foreign exchange row is arbitrarily lower (5, 10, 15 per cent), and the coefficient representing the requirement of "Other Manufacturing" output is correspondingly higher. A possible programming scheme for this is demonstrated in Table 2.8 for a three sector model.

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[1] Interindustry Study of the New Zealand Economy, 1959/60[25], Part 4, Appendices 4A, 4B.

TABLE 2.8

Programming to allow for possible Import Substitution by Activity Producing Commodity 2

	Activities using traditional input mix			Activities using Commodity 2 which has been traditionally imported		
	P_1 Commodity 1	P_2 Commodity 2	P_3 Commodity 3	P_1^* Commodity 1	P_2^* Commodity 2	P_3^* Commodity 3
Row 1	$a_{11} - 1$	a_{12}	a_{13}	$a_{11} - 1$	a_{12}	a_{13}
Row 2	a_{21}	$a_{22} - 1$	a_{23}	$a_{21} + x_1$	$a_{22} + x_2 - 1$	$a_{23} + x_3$
Row 3	a_{31}	a_{32}	$a_{33} - 1$	a_{31}	a_{32}	$a_{33} - 1$
Foreign exchange	m_1	m_2	m_3	$m_1 - x_1$	$m_2 - x_2$	$m_3 - x_3$

$x_i = .05\ m_i$ for 5% import substitution

$= .10\ m_i$ for 10% import substitution

etc.

It may be that import substitution industries are higher cost industries than the overseas manufacturer, and that an amount greater than x_j should be added to the a_{2j} coefficient but this possibility has not been accounted for in this study.

It would be possible to optimise the model given that certain protected industries must continue to exist by specifying minimum levels of output for activities using import substituting manufactured inputs. Say, for instance, that the manufactured goods used by activity P_3 are the output of an industry which is required (for some non-economic reason) to be protected. This can be achieved by placing a minimum restriction on the level at which activity P_3^* - the activity which substitutes manufactured inputs for imports - will be in the solution.

A further step towards more accurate analysis of import substitution industries without a detailed commodity analysis of imports would be disaggregation of the "Other Manufacturing" sector. "Other Manufacturing" is an aggregation of 76 industries of the Department of Statistics 110 industry input-output data for 1959-60[25].[1] The Lincoln model is at present being reconstructed and, among other new features, the "Other Manufacturing" sector will be aggregated into three sectors. The definitions of the new sectors will be as follows:

(1) Non-tradable manufactured goods : this sector consists of industries producing goods which, because of their physical properties, it is not practicable to trade internationally, e.g. brick manufacturing, bread making, bottle manufacturing.

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[1] See Ross & Philpott[31], Appendix II.

(2) Competitive tradable products : this sector is composed of industries which are able to compete successfully with overseas industries producing similar goods. Successful exporting or the potential to export are the main criteria for including an industry in this group.

(3) Non-competitive tradable products : this sector encompasses industries which are not able to export successfully and industries which are protected. This is the sector which is of particular interest in the study of import substitution; it is likely that industries which are not efficient exporters could be efficient export substitutors.

This work is proceeding at Lincoln College under the direction of Professor B.J. Ross. At the time of writing it was incomplete so the optimisation model has been set up without this additional refinement.

2.7 Summary

Conceptually, import substitution (a topic of some relevance to the continued prosperity of New Zealand), can readily be analysed using a linear programming framework. In practice, however, the demands on data - particularly on data of the commodity composition and use of imports - are very great indeed. Of course a considerable amount of detailed statistical detail is available on the commodity composition of imports, but this has to be aggregated into "commodities" which correspond to the "commodities" defined for the input-output data vailable. Also, very little direct information is available on the distribution or use of imported goods. Yet another stumbling block is that very little factual material exists on the true competitive position of New Zealand's manufacturing industries. A long period of absolute protection has meant that many large, apparently efficient industries exist (i.e., efficient in that they compete for resources and markets in the New Zealand economic climate and are not exposed to competition from overseas corporations which may be technically superior or may have access to a more suitable endowment of resources).

A detailed study on protection, import composition and distribution is therefore warranted for New Zealand, and would be of great value to indicative planning models. However, there are alternative, admittedly less satisfactory, ways of treating the problem. The compromises reached have been explained in this chapter.

CHAPTER III

THE APPLICATION OF LINEAR PROGRAMMING TO MACRO ECONOMICS

3.1 Introduction

An indication is given in Chapter I of how linear programming might be used to introduce choice into a standard Leontief input-output model. It is only comparatively recently that attempts have been made to put these principles to practical use.[1] However, the number of projects from which workers in this field can draw experience is increasing rapidly and the purpose of this chapter is to outline the methodology of a few such projects which have influenced this study, and to emphasise their salient features.

Linear programming is one of the mathematical procedures used in activity analysis and in process analysis. These two analytical concepts are substantially the same, except that process analysis deals with individual processes or production techniques rather than aggregated industries or sectors, but there

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[1] The earliest studies in which linear programming has been used to test an economic plan for a whole economy recognised by Chenery and Clark[8] are those by Frisch 1954[14], Chenery & Kretschmer 1956[9]and Chenery 1955, 1958[6, 7].

is not usually a sufficient store of appropriate data or of computing capacity for the principle to be applied to a whole economy. It could be said, therefore, that the present study is concerned with activity analysis and that an "activity" is more closely allied to a Leontief industry or sector[1] than to a particular production technique within an industry, and that each activity is responsible for the production of a particular "commodity". The terms "activity" and "commodity" are used in the more general sense throughout this study.

3.2 Chenery & Kretschmer 1956[9]

A full description of the application of mathematical programming techniques to problems of economic development is given by Chenery and Kretschmer.[2] They suggest that four sets of structural relationships need to be quantified to analyse these problems in this way:

(1) A statement of social goals in terms of economic variables.

(2) A set of production functions.

(3) A set of supply functions for imports and demand functions for exports.

(4) Specifications of the productive resources available.

As has been discussed elsewhere the statement of social goals in mathematical terms is difficult, and at best the programmer can hope to achieve an approximation to reality.[3]

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[1] Note, however, the distinction made between activities and industries in footnote 1, page 14. Industries and sectors may be regarded as synonomous in this study but this is not necessarily always the case.

[2] A similar discussion is contained in Chenery & Clark, ch.11, [8].

[3] Chapter I, Section 1.3.

Usually he will maximise national income or some closely related aggregate which can be expressed as a linear function of economic variables. Because of the particular conditions for which their model was formulated, Chenery and Kretschmer chose to set a level of consumption and to minimise the capital required to achieve it. The assumptions are made that price changes due to a programmed solution do not seriously invalidate the values of parameters, and that the optimal welfare distribution of consumption can be made independently of the pattern of resource use.

The set of production functions needed will usually be formed from the coefficients of a Leontief input-output system. The Leontief concept of a sector or industry is slightly broadened so that alternative technologies as well as alternative sources of supply (locally produced or imported) are available. Chenery and Kretschmer set out a sample system of aggregation for a particular sector and this is reproduced in Table 3.1.

This sector is responsible for the production of three commodities : Commodity 1, Commodity 2 and Commodity 3. These will always be produced in the same proportions x_1, x_2, x_3 ($\sum_1^3 x_i = 1$). Each commodity is produced by a subsector, and within each subsector there are a number of activities representing alternative ways of producing the commodity in question. Thus for subsector 1 there are four ways in which the model can provide Commodity 1 - three production activities labelled A, B, C, and one importing activity labelled M. Similarly Subsector 2 has three alternative activities - two production activities and one importing activity; Subsector 3 has only one production alternative to compete with the importing activity. Commodity k symbolises the requirements of this sector for all other commodities available in the economy.

TABLE 3.1

System of Aggregation for Sector I

Activities	Subsector 1				Subsector 2			Subsector 3		Output Proportions
	1^A	1^B	1^C	1^M	2^A	2^B	2^M	3^A	3^M	
Commodity 1	-1	-1	-1	-1	a_{12}^A	a_{12}^B	0	a_{13}^A	0	x_1
Commodity 2	a_{21}^A	a_{21}^B	a_{21}^C	0	-1	-1	-1	a_{23}^A	0	x_2
Commodity 3	a_{31}^A	a_{31}^B	a_{31}^C	0	a_{32}^A	a_{32}^B	0	-1	-1	x_3
Commodity k	a_{k1}^A	a_{k1}^B	a_{k1}^C	0	a_{k2}^A	a_{k2}^B	0	a_{k3}^A	0	
Foreign Exchange	0	0	0	g_1	0	0	g_2	0	g_3	
Capital	C_1^A	C_1^B	C_1^C	0	C_2^A	C_2^B	0	C_3^A	0	

Source: Table 1, page 373 [9]. (The positive and negative signs have been alternated from the original so they conform to usual linear programming nomenclature.)

The whole of the production function information (input structures of all the activities) is moulded into a system of equations which dictate that the total use of any commodity does not exceed the total supply.

A generalised equation of this type would be:

Domestic production of commodity i	+	Imports of commodity i	$\geq$	Interindustry use of commodity i	+	Public & private consumption of i	+	Exports of commodity i

A reconciliation equation for commodity 3 of Table 3.1 could be:

$$X_3A + X_3M \geq \sum_j a_{3j}X_j + c_3C + E_3 \qquad \ldots. (3.1)$$

where X_j is the level of output of activity j

C is the level of consumption.

E_3 is the level of exporting of commodity 3

a_{3j} is the input of commodity 3 per unit of activity j.

c_3 is the amount of commodity 3 per unit of consumption.

Ideally, the total demand for a commodity will equal its total supply, a situation referred to as competitive equilibrium, but the mathematically weaker inequality is all that is necessary to ensure a feasible economic structure.

If it is assumed that imports of commodities are a small proportion of world trade so that importers face perfectly elastic supply curves, imports can be handled as alternative sources of supply to domestic activities. The activities superscripted M in Table 3.1 are imported activities; the foreign exchange cost of importing one unit of commodity i is g_i. The assumption that exporters face perfectly elastic demand curves is often more difficult to accept, and in their paper Chenery and Kretschmer express the price of exports as a decreasing linear function of their level. This results in a quadratic equation in the system so that non-linear rather than linear programming methods are required to solve the model.

Let E_j be the level of exporting of commodity j

M_j be the level of importing of commodity j

D be the maximum foreign exchange deficit

h_j be the unit price of exports of j

g_j be the unit price of imports of j

The foreign exchange restriction is therefore:

$$\sum_j g_j . M_j - \sum_j h_j E_j \leqslant D \ldots . \qquad (3.2)$$

Let the price of exports be a diminishing linear function of their level:

$$h_j = \gamma_j + \rho_j E_j \qquad (\gamma > 0, \rho < 0) \qquad (3.3)$$

The constraint now becomes

$$\sum_j g_j M_j - \sum_j \gamma_j - \sum_j \rho_j E_j^2 \leqslant D \ldots . \qquad (3.4)$$

However, Chenery and Clark explain that the linearity of the model can be maintained by having several exporting activities.[1]

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[1] See footnote on p.291 of Chenery & Clark [8]. See also the suggested method for accommodating diminishing returns in Chapter I, Section 1.5.

Resources which are limited in supply are easily accommodated if the rates at which they will be used by the various activities are known. Existing stocks of capital goods and the size of the labour force are the usual physical factors which constrain the overall level of activity. In the Chenery-Ketschmer model there is no specific treatment of the capital stocks available to each sector or of investment purchases by each sector. There is simply an equation which computes the sum of the individual capital requirements of the sectors. This constitutes the objective function of the program and is minimised by the optimising routine. Also it will generally be desirable to balance overseas payments with export earnings, or at least to have a maximum allowable deficit, and an equation expressing this constraint will usually be included (see equation 3.2 above).

Blyth & Crothall, 1965[2].

There are four kinds of activity in the Blyth-Crothall model of the New Zealand economy:

(a) Current production activities,
(b) Exporting activities,
(c) Importing activities,
(d) A consumption activity.

Investment in the economy is accounted for by providing two types of current production activity - production from existing plant and production using new plant. Production from existing plant is restricted in each sector by a capacity measure representative of the stock of capital available for use; the coefficients for these activities are the current input requirements per unit of output. The coefficients for the production from new plant account for the current input requirements plus the inputs of capital goods required to make a unit of capacity available to that sector. The authors explain that the production using new capital activities are composite activities. Consider such an activity, A_{20}; this can be regarded as a combination of two activities A'_{20} and A''_{20} by the relation:

$$A_{20} = A'_{20} + k A''_{20} \tag{3.5}$$

where

A'_{20} is the level of current production using new plant.

A''_{20} is an investment or capital formation activity which produces the appropriate plant for A'_{20}.

k is the capital-output ratio which states how many units of investment are required to provide capital with the capacity to produce one unit of A'_{20}.

This definition ignores the time lag between capital formation and its use, but this was not considered to be a serious drawback to the model's ability to give a reasonable indication of the most desirable economic structure.

The exporting, importing and consumption activities follow the same pattern as those used by Chenery and Kretschmer. However, it is worth noting that to earn a unit of foreign exchange output is required from sectors other than the one producing the commodity being exported. This is to account for ancillary internal costs specifically associated with the activity of exporting, e.g. wharf handling expenses, insurance costs, storage. The model is an annual model so that all variables are defined as levels or amounts for a particular year, and the program maximises the level of consumption for that year.

The constraints to the linear programming problem are similar to those used by Chenery & Kretschmer. There are production reconciliation rows, a foreign exchange row, a labour constraint, and maximum limits on the levels of exporting activities which are analogous to those used in the earlier study. A land constraint is also included but this does not constitute a divergence from the fundamental logic of the other resource restrictions. In addition the output in each sector is restricted by the size of a stock of capital. When this stock is exhausted (it is "used" at the rate determined by a capital output ratio for each sector) further output of the commodity in question is possible only from activities using new capital.

Total investment (or, in terms of the variables of the model, the production from activities using new capital) is restricted by the availability of "waiting". This concept is rather abstract and is dealt with sparingly in Blyth & Crothall's paper. The following description can be regarded as this author's understanding of it. The concept is intended to combine the current cost and time (discounting) aspects of investment expenditure. Waiting is measured in years and when multiplied by its price (dollars per year) gives the total interest cost of new investment. The price of waiting is regarded as a constant and is of the nature of an average interest rate, or a rate of preference between a dollar's worth of consumption now and a dollar's worth of consumption one year later. Waiting is therefore representative of the greater opportunity costs (discounted future consumption sacrificed) or "loss" of present value of longer term investments : a large investment for which the payback is quick may have a larger present value than a much smaller investment which does not yield positive cash flows until a considerable time has elapsed. The total amount of waiting available in a given year should be related to the economy's ability to finance new investment and service the interest costs until the capital goods purchased can "pay their own way". The concept is akin to the identity of static economic theory that total savings equals total investment; but it has an additional dynamic attribute which accounts for the fact that investments in different projects have different payback times as well as different initial lump sum purchase requirements.

The data for the model comes mainly from the 1954-55 interindustry study carried out by the New Zealand Department of Statistics [26], which is rather limited in its scope, and the authors give their model the status of "a pilot programming model". Nevertheless, they define alternative activities by making arbitrary adjustments to the basic data and thus display clearly the flexibility linear programming gives to the national economic planner. Hence allowance is made for increasing marginal costs in farming, and choice is available between capital intensive and labour intensive technologies for the production activities using new capital.

The model was solved for the year 1954-55 and the manner in which the solution should be interpreted is demonstrated. It is emphasised that a sensitivity analysis of the solution is of greater value to the planner than the actual values of the solution. This involves examining the possibility that sub-optimal solutions might be acceptable; and an interpretation of the shadow prices or dual solution. Thus it is possible to isolate "bottlenecks" or areas of strain within the economy. The likely consequences of some policies can also be tested in this way. Priorities for planning should be based on this type of analysis, which reveals the constraints that have the greatest "cost", rather than on the actual numerical solution.

3.4 Manne, 1963 [21].

Manne's programming model is an example of process analysis rather than activity analysis as the variables are sufficiently disaggregated to represent particular production techniques and the input data is of an engineering nature. However, the author does not claim to have treated the whole economy with this degree of detail but that he has encompassed the "key sectors" of the economy (Mexico). The level of output in other sectors is treated in much the same way as exogenous final demand would be if the activity analysis approach was taken. The distinction between what is a "key sector" and what is not was made on the basis of the interests of the organisation sponsoring the study, Nacional Financiera, S.A., and of the limited personnel and time available to carry out the project. Manne's approach would seem to be in line with a comment made by Chenery and Clark on the practical use of programming methods for planning economic development : "The more likely evolution of programming technique is therefore first to develop models which only include alternative activities in sectors where they are critical to the solution."[1] A ten year planning horizon was chosen as a "pragmatic compromise" between the difficulty of realistically estimating the rate of technological change over a longer period, and the distortion of reality which would occur due to ignoring lags between investment and output in shorter time period models.

A feature of the model is that it incorporates endogenous generation of demand for capital equipment. That is, an investment flow is necessary in order that a capital stock might exist and be used for current production. The model programs <u>increases</u> in annual production flows and assumes that the capital stocks to

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[1] Chenery and Clark, p.299[8].

support the increases must also be produced during the ten year horizon. However, this capital need not all be formed in the final year - the year to which the programmed solution applies; that is, the investment flow in the final year does not have to be equal to the full value of the increase in the size of the capital stock. At the same time, it could reasonably be expected that the level of investment would increase during the period, possibly by a fixed proportion of its level each year.

Let the annual rate of growth of capacity be g : let the capacity of sector i at the beginning of year 1 (the first year of the planning horizon) be X_i.

Therefore the capacity of sector i at the beginning of year 10 would be:

$$(1 + g)^{10} X_i$$

The increase in capacity (to be financed by investment during the period) equals:

$$[(1 + g)^{10} - 1] X_i$$

The amount of investment which would take place during year 10 would be g multiplied by the capacity at the beginning of year 10:

$$g(1 + g)^{10} X_i$$

Therefore the fraction of the total investment during the ten year horizon that takes place in the final year is:

$$\frac{g(1 + g)^{10}}{[(1 + g)^{10} - 1]}$$

Manne used .15 as a linear approximation to this value. This means the model dictates that 15 per cent of total investment during the period must occur in the final year. An indication of the accuracy of this technique is given in Table 3.2. Again he has

TABLE 3.2

Comparison of Linear Approximation to Proportion of Investment Occurring in Final Year of Ten Year Horizon and Precise Calculation

Capacity growth rate	g	5.0%	7.5%	10.0%
Linear approx.	$.15\,[(1+g)^{10}-1]\,X_i$	$.094\,X_i$	$.159\,X_i$	$.239\,X_i$
Precise Calc.	$g(1+g)^{10}\,X_i$	$.081\,X_i$	$.155\,X_i$	$.259\,X_i$

Source: p.384, Manne[21]

shown how to achieve a reasonable approximation to a theoretically more desirable but, because of limited research resources or techniques, impracticable analytical structure.

Another novel feature of this work is that the objective function is to minimise the foreign exchange required as loans by the key sectors. The Mexican economy has massive under-employment of labour and any improvement of this situation will require massive imports of capital equipment. Planners will be more interested in the structure which will achieve a certain set of consumption targets and minimises the strain on overseas borrowing than in a structure which will maximise consumption given a maximum foreign exchange deficit. It is obvious that foreign exchange is a bottleneck to growth; the minimum strain put on the economy by that bottleneck is the major concern of economic strategists. Of course, this ignores the very important fact that resources will need to be used to educate the surplus labourers in order that they might be able to use the imported equipment for production.

3.5 Moustacchi, 1964 [24].

The model described by Moustacchi was developed by Desport, Raiman and Moustacchi and has been used in the formulation of France's Fifth Plan. Not only is the article interesting for the model outlined, but because particular attention is paid to the interpretation and significance of the dual solution to national linear programming models.

Two production techniques are available to each sector during the planning horizon which is divided into two periods. "Average" or traditional technologies can be used in each of these periods; production using" modern" technologies is allowed in the second period if the relevant investment activity is activated for the first period. Also there is provision for production using "overheating techniques" in the first period. These activities allow production in excess of the capital stock in the first period, but the productivity of labour is lower than for the "average technique". The labour force is grouped so that labour must come from a particular group for each sector. Restrictions are placed on the movement of labour from one sector to another. The objective function for the model exhibits a utility idea, and is a function of consumption in each of the periods and investment; the goal of society is taken to be maximisation of the present value of consumption plus the residual value of capital equipment.

An alternative to programming for the optimum allocation of resources among producing sectors inan economy would be the optimum valuation of the resources so that they would be used by the various sectors in the optimum proportions. The dual solution to a linear program which allocates resources for the economy is often interpreted as such a price system. If any restriction in a programming problem limits the value of the objective function, that restriction may be regarded as a cost whose quantitative expression could be the amount by which the objective could be increased per unit of relaxation of the restriction. It is easily shown that the values of the dual solution to a linear programming problem is just such a system of costs, e.g.,

Consider the linear programming problem

$$\text{Max } Z = CX$$

subject to

$$AX \leqslant b$$

$$X \geqslant 0$$

where X is a vector of primal variables

b is a vector of resource availability

C is a vector of objective function unit values

A is a matrix of coefficients

The dual to this problem is

$$\text{Min } Z = b'W$$

subject to

$$A'W \geqslant C$$

$$W \geqslant 0$$

where W is a vector of dual variables.

Partially differentiating the objective of the dual in terms of the b vectors:

$$\frac{\partial Z}{\partial b} = . W$$

or $$Z = b_1 W_1 + b_2 W_2 \ldots . + b_m W_m$$

$$\therefore \quad \frac{\partial Z}{\partial b_1} = W_1 \quad ,$$

$$\frac{\partial Z}{\partial b_2} = W_2 \quad ,$$

$$\vdots$$

$$\frac{\partial Z}{\partial b_m} = W_m \quad .$$

$\frac{\partial Z}{\partial b_i}$ is the marginal value of the i^{th} restriction to the system of equations.

W_i is the value of the i^{th} dual variable.

This shows the values of the dual variables are unit values of the commodities or resources limited by the restrictions of the primal. When the objective function is expressed in dollars (as it normally is in models of this nature) these values are competitive equilibrium dollar values of scarce resources or the output of sectors. Where the unit of the restriction equation is also dollars, as is usually the case for the measurement of sectoral output, the values of the dual solution would ideally be one. Imperfectations of the market mechanism and inconsistencies within the model will often mean that only a poor approximation to this ideal is achieved.

Moustacchi concludes that his model produces relative prices which are valid only when they approximate to the prices of a "reference outline" or initial optimum situation. When prices deviate from this pattern it is not easy to be confident that the input proportions for the productive sectors and consumption are reasonable approximations to the true ones. In addition, input proportions are likely to change with the level of activity. It might be possible to circumvent some of these difficulties by devising financial constraints for the system. In spite of such problems, the shadow price solution to a macroeconomic linear program will indicate which sectors or resources are most critical to the economy in question.

CHAPTER IV

A LINEAR PROGRAMMING MODEL OF THE NEW ZEALAND ECONOMY

A case has been presented for the use of quantitative methods for national economic planning, and examples given of the use of linear programming for this purpose. It is proposed in this chapter to formally outline a linear programming model for the New Zealand economy, and to describe a numerical form of the model which will complement other research in the same field.

4.1 Definition of Variables

The following definitions and symbols will apply to the variables of the model:

N - the number of activities;

R - the number of sectors (commodities)

P_j - the value in constant prices of the output of activity j in the target year; $j = 1, 2 \ldots N$;

I_j - the value in constant prices of purchases of net investment goods by activity j in the target year, $j = 1, 2 \ldots N$;

C - the total value in constant prices of consumption plus government expenditure by the indigenous population in the target year;[1]

[1] "Indigenous" in this context refers to population living in New Zealand before the period for which the model programs. "Immigrants" are people who migrate to New Zealand during the planning horizon.

C_M - the total value in constant prices of consumption plus government expenditure by immigrants, in the target year;

E_j - the level of exporting, valued in constant domestic prices, of the output of sector j in the target year, $j = 1, 2 \ldots . R$;

M - the number (thousands) of immigrants during the planning period;

a_{ij} - the output of sector i required per unit of output of activity j,
$j = 1, 2 \ldots . R$,
$j = 1, 2 \ldots . N$;

a_{mj} - the level of importing, valued in constant domestic prices, required per unit of output of activity j,
$j = 1, 2 \ldots . N$;

b_{ij} - the output of sector i required per unit of net investment by activity j,
$i = 1, 2 \ldots . R$,
$j = 1, 2 \ldots . N$;

b_{mj} - level of importing, valued in constant domestic prices, required per unit of net investment by activity j,
$j = 1, 2 \ldots . N$;

c_i - output of sector i required per unit of consumption plus government expenditure,
$i = 1, 2 \ldots . R$;

c_m - level of importing, valued in constant domestic prices, required per unit of consumption plus government expenditure;

e_{ij} - output of sector i required per unit of exporting of the output of sector j,
$i = 1, 2 \ldots . R$,
$j = 1, 2 \ldots . R$;

k_j - capital-output ratio appropriate to activity j,
$j = 1, 2 \ldots . N$;

g_i - capital formation required by activity i per unit of immigration, $i = 1, 2 \ldots . N$;

d_j - depreciation as a proportion of total output for activity j, $j = 1, 2 \ldots . N$;

s - amount of savings achieved per unit of consumption plus government expenditure by the indigenous population;

s_M - amount of savings achieved per unit of consumption plus government expenditure by the immigrant population;

l_j - labour-output ratio appropriate to activity j in the target year (inverse of labour productivity ratio), $j = 1, 2 \ldots . N$;

K_i - the capital stock available for production by activity i at the beginning of the planning horizon, $i = 1, 2 \ldots . N$;

Q_i - maximum level of exporting of the output of sector i in the target year, $i = 1, 2 \ldots . R$;

D - maximum deficit in current account of overseas transactions in the target year.

L - the projected labour force available in the target year assuming zero net annual immigration;

TC - total level of consumption plus government expenditure in the target year;

g_c - minimum consumption plus government expenditure required per unit of immigration.

4.2 Algebraic Statement of Model

Objective function :

$$\text{Maximise } Z = C \tag{4.1}$$

Restrictions :

(1) Reconciliation of current production,

$$0 \geqslant \sum_{j}^{N} (a_{ij} - \partial_{ij})P_j + \sum_{j}^{N} b_{ij}I_j + \sum_{j}^{R} e_{ij}E_j + c_iC + c_iC_M \qquad (4.2)$$

$i = 1, 2 \ldots . R$;

∂_{ij} is the Kronecker delta

(2) Reconciliation of capital stocks,

$$K_i \geqslant k_iP_i - 6.6667\, I_i + g_i\, M \qquad (4.3)$$

$i = 1, 2 \ldots . N$;

(3) Reconciliation of overseas exchange transactions,

$$D \geqslant \sum_{j}^{N} a_{mj}P_j + \sum_{j}^{N} b_{mj}I_j + c_mC + c_mC_M - \sum_{j}^{N} E_j \qquad (4.4)$$

(4) Savings reconciliation,

$$0 \geqslant \sum_{j}^{N} d_jP_j + \sum_{j}^{N} I_j - sC - s_MC \qquad (4.5)$$

(5) Labour force reconciliation,

$$L \geqslant \sum_{j}^{N} l_jP_j - .5\, M \qquad (4.6)$$

(6) Maximum exporting restrictions,

$$Q_i \geqslant E_i \qquad (4.7)$$

$i = 1, 2 \ldots . R$;

(7) Minimum consumption requirements for immigrants,

$$0 \geqslant g_c M - C_M \tag{4.8}$$

(8) Row which calculates total consumption,

$$0 = -C - C_M + TC \tag{4.9}$$

(9) Non-negativity requirements,

$$P_j , I_j , E_j , M , C , C_M , TC \geqslant 0 \tag{4.10}$$

$$j = 1, 2 \ldots . N.$$

4.3 Explanation of the Model

As will have been observed from the definition of the variables there are five groups of variables used in the model:

(a) Current production activities,

(b) Net investment activities,

(c) Consumption activities,

(d) Exporting activities,

(e) An immigration activity.

The coefficients for the current production activities are derived from input-output data and are adjusted so that they include expenditure on the replacement of worn or obsolete capital equipment.[1] Hence the investment activities refer to net rather than gross investment and the whole of the investment purchases can be considered to be added to the capital stock. The consumption

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[1] A full description of the calculation of the various coefficients and data sources is given in Appendix I.

and exporting activities are analogous to those used by Blyth and Crothall [2] and others. An immigration activity is included as a means of augmenting the labour supply; the activity has capital coefficients to account for the housing and public facility (hospitals, schools etc.,) requirements of the additional population. There is no need to have coefficients for other capital requirements caused by immigratns as calculated by the Monetary & Economic Council [23], as the interdependent properties of this model ensure that these are accounted for.

The objective function of the model is to maximise the value of consumption plus government expenditure by the indigenous population. At first sight this appears to be a rather pitiless approach and that maximisation of total consumption (TC) would be a more humanitarian goal. However, it is generally recognised that the level of consumption of an economy is not a particularly good barometer of economic welfare, but the level of consumption per head is reasonably satisfactory. Due to problems of non-linearity, it is not possible to optimise consumption per head in a linear programme which has a variable labour force (and population). A ploy adopted in this model is intended to go some way towards resolving this problem: the model forces a minimum amount of consumption to be "set aside" for the immigrant population and maximises the level of consumption for the original population. No claim is made that the model does anything to distribute income among the population, and it is very likely that in a real situation, immigrant workers would receive a share of the maximand.

There are nine groups of equations which restrict the model:

(1) The production reconciliation rows ensure that sufficient is produced in the target year to match the total amount of each commodity used. The rationale of these constraints has already been explained.[1] There is one equation of this type for each commodity; thus in the formalised model described in this chapter there are R such equations.

(2) The capital stock reconciliation rows ensure that the level of output in each sector does not exceed its base year capacity unless the capital stock has been augmented by investment during the planning period. When investment does occur in a particular sector, the appropriate investment activity makes certain that the current output for each unit of investment is accounted for in the production reconciliation rows. Since this is an annual model investment is measured as an annual flow for the final year of the planning horizon; but the capital stocks available for production in that year will include capital formed due to investment flows in all the years of the period. Consequently, for programming purposes each unit of investment is regarded as contributing 6.6667 units rather than 1.0000 units to the stock of capital for that sector.[2] As each activity in the model is treated as though it had its own specialised capital stock, there is an equation of this type for each activity; thus there are N of these equations.

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[1] Chapter III, Section 3.2.

[2] The value of 6.6667 is not a generalised value but is the particular value chosen for the eight year planning horizon of this study. The problem of reconciling stocks and flows in an annual model which spans an horizon larger than one year has been recognised by Manne [21] and is discussed in Chapter III, Section 3.4. And explanation of the value 6.6667 is given in Appendix I.

(3) Reconciliation of current overseas exchange transactions prevents growth in the economy while massive deficits occur in the current overseas account, a situation which cannot be allowed to continue indefinitely and certainly should be guarded against in a quantitative planning exercise. However, for the sake of development a certain maximum deficit on current account will normally be tolerated. There is one equation of this type in the model; import requirements of the production, investment, and consumption activities tend to exhaust or "use up" the supply of foreign exchange while the exporting activities augment it.

(4) There is one equation in the model labelled the savings reconciliation row; its role is to prevent the ratio of consumption to investment from becoming unrealistic. Investment is often thought of as a sacrifice of consumption "now" in order that consumption might occur at some future time. This is the basic motive behing all saving and it is a well known identity of static economics that savings equal total gross investment. It is assumed here that, in aggregate, consumers tend to save a constant proportion of their income so that the ratio between savings available for investment and consumption is a constant. Each dollar of net investment requires a dollar of savings as well as a set of current inputs (equal to one dollar in value) from the producing sectors; each dollar of depreciation expenditure also requires a dollar of savings. In the programming model savings are "allowed to be available" in proportion to the level of consumption; they are "used up" by the production activities in amounts required for depreciation, and by investment activities to account for net investment expenditure. This row restricts the total capital formation in the model.

(5) There is one labour constraint which reconciles the total demand for labour with estimated labour supply. The labour requirements of producing activities are expressed as labour-output ratios (inverses of labour productivity coefficients). The model has the capacity to generate more labour by means of the immigration activity.

(6) Each of the exporting activities has an upper limit in recognition of the fact that opportunities to sell exports are not unlimited. The upper limits set should be based on projected trends and on knowledge gained from separate studies into the markets for the individual products.

(7) The reason for the minimum consumption requirement for immigrants has been explained above. The value of the parameter g_c can be regarded as a policy parameter since setting it at a lower value is likely to allow a greater level of immigration.

(8) A row is included to calculate the total level of consumption : the sum of consumption by the indigenous and immigrant populations. This is done by having a total consumption activity (TC) which "demands" one unit from the row; and each unit of consumption "supplies" one unit to the row. By making the row an equality it has the effect of adding the two consumption activities. The overall solution is not affected as the total consumption activity has no other coefficients and can be included in the basis without using any resources.

(9) Non negativity requirements for the activities of the model are necessary in order that the solution makes economic sense. The linear programming optimising routine fore-ordains that these constraints are satisfied.

4.4 Relationships to Blyth-Crothall Model

The Blyth-Crothall model described in Chapter III was one of the impelling forces behind this study and the model just described has many attributes in common with it. The production reconciliation rows, the labour constraint, the foreign exchange constraint, and the constraints on the levels of the exporting activities are all analogous to the corresponding rows of the Blyth-Crothall model. The coefficients for the production activities, the consumption activities and the exporting activities, have been derived for the present study in the same manner as the corresponding coefficients were in the earlier study.

Differences occur in that the present model has no land constraint and that savings are endogenously generated in proportion to consumption rather than a fixed amount being available in the form of "waiting". The land constraint has been omitted because, for the present, there is merely one farming activity and land was not considered to be one of the important factors limiting the level of activity in farming as a whole. Blyth and Crothall included the constraint as a means of attributing higher marginal costs to more intensive farming. When the present model comes to the point that it is being used to analyse a disaggregated farming sector and to feature increasing marginal costs for farming, the necessity of a land constraint should be investigated. The inclusion of endogenously generated savings is thought to be an improvement, although there is some difficulty as to the ratio of saving to consumption that should be used, and the "waiting" concept has a dynamic element which is not present when a simple savings constraint replaces it. A noticeable difference between the models is the manner of treating investment. Blyth and Crothall do not provide distinct investment activities but incorporate investment expenditure into production which exceeds the existing levels of capital stocks. The reasoning supporting the investment activities of the present model is similar but the new capital formation is subjected to the same input-output coefficients for current production as the original capital stocks. The current component of the coefficients for production from new capital activities of the Blyth-Crothall model reflect new technologies and are therefore different from the coefficients for production from existing capital. The example of inclusion of competitive importing activities has not been followed due to data difficulties.[1] The immigration activity is a feature not included in the Blyth-Crothall model, although the authors suggest at the end of their article how the shadow prices of labour could be restricted by adding another constraint to the dual problem. This would be equivalent to adding an immigration activity and a leisure (slack labour) activity to the primal. Immigration would have a cost which would be accounted for as a negative component of the objective function rather than as a specific requirement of capital and consumption.

There is considerably more choice of activities in the Blyth-Crothall model in the form of activities displaying alternative technologies, competitive importing activities, and activities allowing for diminishing marginal returns in farming and in exports of processed primary products. However, the coefficients for these activities were largely of an arbitrary nature and were included mainly for purposes of exposition. These refinements can easily be included in the model described in this chapter, but it was thought unnecessary to do so unless realistic data could be obtained.

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[1] See Chapter II.

4.5 Present Numerical Form of the Model

The initial tableau for the linear programming model as it has been used in this study to explore the possibilities for economic development in New Zealand, is laid out in Table 4.1. A few modifications have been made to the generalised structure.

It was recognised in the Lincoln projection model that capital-output ratios were not a satisfactory way of handling all forms of investment.[1] The idea of "autonomous investment" was, therefore, also used in this model for some investment by government and investment to houses. This has resulted in the addition of two investment activities P_{31} and P_{33} for which there are minimum levels for the target year. These activities are not activated via capital-output ratios in the same way as the other investment activities, e.g.

$$228 \leqslant 1.0000\ P_{31} \qquad (4.11)$$

This constraint states that the investment activity P_{31} must be at least at the level of $228 million in the target year. The coefficient for P_{31} is 1.0000 rather than 6.6667 as the constraint is concerned only with the final year's investment flow; the size of the relevant capital stock is not of direct concern to the planning model; the level of investment is decided upon independently, or possibly "autonomously", and it is irrelevant to this model whether it bears any relation to the capital stock or not. An additional production activity is also added. This is due to the fact that some of the capital used by the "Ownership of Property" sector is not housing but premises rented to productive sectors, and that the requirement

[1] Chapter I, Sec. 1.4.

of this type of capital should be decided within the model by a capital-output ratio. Thus there is an activity, P_{17}, which does not have a capital-output ratio. The only activities which have a requirement of the output of this sector are the consumption activities as this is defined to be the only way that housing (payment of rent to the "Ownership of Property" sector) is consumed.

The model is given a choice of consumption activities. These have differing amounts of import substitution of manufactured final goods. This is intended to be a first step towards incorporating import substitution opportunities in the interindustry flows in the manner suggested in Chapter II.[1] Substitution of imported final goods is a more likely possibility, from a technical viewpoint, than the substitution of imported components. That is, industries are likely to arise which assemble imported components as a substitute to importing the completed object.

The time horizon chosen for the model was eight years. The logic for this period was similar to that used by Manne.[2] Eight rather than ten years was used for consistency with the projections made by Ross and Philpott [30], and for comparison with the Targets set for 1972-73 by the National Development Conference.

Details of the sources and calculation of coefficients in Table 4.1 are given in Appendix I.

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[1] Table 2.8.

[2] Chapter I, Sec. 1.4.

The activities shown in Table 4.1 may be categorised as follows:

P_1 to P_{17} are current production activities. They correspond to sectors listed in Appendix I. Sector 16 is represented by two activities, P_{16} and P_{17}. This is to account for the fact that some of the capital formation for this sector is exogenous to the model.

P_{18} to P_{33} are net investment activities. These also correspond to the sectors listed in Appendix I, except that Sector 14, "Services to Households" does not require a capital stock. Sector 16 has two investment activities, P_{32} and P_{33} for the same reason it has two current production activities.

P_{34} to P_{36} are the consumption activities.

P_{37} to P_{43} are the exporting activities available. These correspond to the first seven sectors listed in Appendix I.

P_{44} is the immigration activity.

P_{45} is the immigrants consumption activity.

P_{46} is the total consumption activity.

The roles of the rows of Table 4.1 are as follows:

R_1 to R_{17} are restrictions on current production.

R_{18} to R_{33} are capital stock reconciliation rows.

R_{34} is the foreign exchange reconciliation row.

R_{35} is the savings reconciliation row.

R_{36} is the labour force reconciliation row.

R_{37} to R_{43} are the maximum restrictions on the exporting activities.

R_{44} is the specification of minimum consumption requirements for immigrants.

R_{45} is the row which calculates total consumption.

			CURRENT PRODUCTION ACTIVITIES														
			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
			Farming	Forestry	Forestry Proc.	Hunting & Fishing	Mining	P.P.P.	Other Mfg.	Bldg & Constr.	Public Utilities	Transp. & Comm.	W/S. & Retail Trade	Banking & Insurance	Services	Services to H/holds	Services to Govt.
Maximize																	
1	0	≥	-.8026	-	-	.0082	-	.6822	.0235	-	.0010	.0012	.0009	-	.0295	-	-
2	0	≥	.0017	-1.0000	.1234	-	.0023	.0002	.0001	.0004	.0050	.0003	.0002	-	-	-	-
3	0	≥	.0120	.0033	-.7791	.0094	-	.0154	.0272	.0945	.0080	.0056	.0218	.0103	.0076	-	-
4	0	≥	.0002	-	-	-.9930	-	.0002	.0002	-	-	.0003	-	-	.0023	-	-
5	0	≥	.0009	-	.0036	-	-1.0000	.0052	.0050	.0258	.0218	.0045	-	-	-	-	-
6	0	≥	.0025	-	-	-	-	-.9358	.0063	-	-	.0016	.0024	-	.0300	-	-
7	0	≥	.1223	.0747	.0399	.1112	.0881	.0286	-.8509	.1583	.0678	.1549	.0660	.0603	.0980	-	-
8	0	≥	.0072	.0178	.0127	.0164	.0630	.0035	.0060	-.8784	.0212	.0203	.0161	.0858	.0166	-	-
9	0	≥	.0075	.0033	.0180	.0094	.0223	.0078	.0099	.0033	-.6820	.0071	.0119	.0254	.0118	-	-
10	0	≥	.0323	.0255	.0695	.0378	.1934	.0299	.0524	.0467	.0292	-.8810	.0454	.0618	.0343	-	-
11	0	≥	.0557	.0424	.0556	.0589	.0520	.0260	.0618	.0821	.0333	.0319	-.9782	.0200	.0289	-	-
12	0	≥	.0049	.0076	.0110	.0108	.0172	.0025	.0059	.0072	.0054	.0047	.0415	-.9707	.0144	-	-
13	0	≥	.0122	.0127	.0201	.0238	.0126	.0028	.0188	.0094	.0052	.0152	.0698	.0807	-.9249	-	-
14	0	≥	-	-	-	-	-	-	-	-	-	-	-	-	-	-1.00	-
14	0	≥	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-1.00
16	0	≥	-	.0097	.0029	-	.0024	.0006	.0056	.0023	.0018	.0046	.0324	.0249	.0385		
17	0	≥	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	1556	≥	1.5000														
19	84	≥		2.0000													
20	97	≥			.3487												
21	21	≥				1.9300											
22	45	≥					1.0000										
23	294	≥						.4260									
24	540	≥							.3487								
25	1090	≥								1.5207							
26	1084	≥									6.1223						
27	1266	≥										2.3974					
28	654	≥											.7478				
29	223	≥												1.4217			
30	164	≥													.2361		
31	228	≤														-	-
32	700	≥															
33	350	≤															
34	60	≥	.0458	.0468	.0783	.1162	.1040	.0232	.2041	.0533	.0555	.0794	.0226	.0309	.0611	-	-
35	0	≥	.0486	.0806	.0433	.0364	.1264	.0140	.0269	.0218	.0866	.0596	.0367	.0658	.0296	-	-
36	1131	≥	.0871	.1500	.0732	.3529	.0968	.0420	.1122	.1068	.0570	.1417	.1391	.0413	.2871	.2871	.2871
37	383	≥															
38	5	≥															
39	44	≥															
40	10	≥															
41	1	≥															
42	636	≥															
43	212	≥															
44	0	≥															
45	0	=															

TABLE 4.1 LINEAR PROGRAMMING TABLEAU

		NET INVESTMENT ACTIVITIES																CONSUMPTION ACTIVITIES			EXPORTING ACTIVITIES							IMMIGRATION		
P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45	P46
Ownership	Ownership	Farming	Forestry	Forestry Proc.	Hunting & Fishing	Mining	P.P.P.	Other Mfg.	Bldg & Constr.	Public Utilities	Transp.& Comm.	W/S. & Retail Trade	Banking & Insurance	Services	Govt. (autonomous)	Ownership	Ownership	No Import Subst'n.	5% Import Subst'n.	10% Import Subst'n.	Farming	Forestry	Forestry Proc.	Hunting & Fishing	Mining	P.P.P.	Other Mfg.	Immigration	Immigrants' Consumption	Total Consumption
																		1.0	1.0	1.0										
-	-	.0487							-	.0013	-					.0004	.0004	.0235	.0235	.0235	.9175								.0235	
-	-	.0012							-	.0056	-							.0016	.0016	.0016		.8958							.0016	
.0099	.0099	.0351							.0035	.0196	.0119	.0024	.0088	.0103				.0025	.0025	.0025			.9263						.0025	
-	-	-							-	-	-							.0017	.0017	.0017				.8615					.0017	
-	-	.0014							-	-	-							.0027	.0027	.0027					.9200				.0027	
-	-	-							-	-	-							.0600	.0600	.0600						.9272			.0600	
.0508	.0508	.3737	.2301	.0664	.3694	.2604	.2729	.1693	.3465	.2327	.2145	.4393	.0811	.2943	.05	.0356	.0356	.2531	.2569	.2607							.9200		.2531	
.1355	.1355	.1665	.2423	.4602	.2723	.3863	.3662	.3508	.0965	.4034	.3187	.3571	.7964	.3897	.88	.9116	.9116	.0162	.0162	.0162	.0002	.0002	.0002	.0003	.0002	.0002	.0002		.0162	
.0184	.0184	-		-	-		-	-	-	-	-							.0195	.0195	.0195	.0007	.0009	.0006	.0011	.0007	.0006	.0007		.0195	
.0082	.0082	.0421	.0886	.0354	-	.0730	.0421	.0268	.0642	.0370	.0365	.0302	.0247	.0347	.01	.0026	.0026	.0425	.0425	.0425	.0469	.0592	.0419	.0786	.0455	.0414	.0455		.0425	
.0141	.0141	.1628	.2520	.0442	.2042	.1442	.0518	.0745	.1735	.0444	.0786	.1090	.0231	.0580	.01	.0066	.0066	.1771	.1771	.1771	.0211	.0267	.0189	.0354	.0205	.0186	.0205		.1771	
.0288	.0288	.0019	-	-	-	.0002	-	.0040	.0015	-	-	-						.0234	.0234	.0234	.0049	.0061	.0043	.0081	.0047	.0043	.0047		.0234	
.0233	.0233	-	-	.1416	-	-	.0078	.0951	-	.0218	.0073	.0208	.0175	.0289	-	.0301	.0301	.0863	.0863	.0863	.0064	.0081	.0057	.0107	.0062	.0057	.0062		.0863	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			.0081	.0081	.0081									.0081	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			.0885	.0885	.0885										
-.9826	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						.0023	.0030	.0021	.0041	.0022	.0020	.0022			
	-.9286																	.0942	.0942	.0942									.0942	
		-6.6667																												
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													-6.6667																	
														-6.6667														.9280		
															1.0000															
9.4224																-6.6667												2.0650		
																	1.0000													
.0091	.0091	.1665	.1870	.2522	.1541	.1362	.2589	.2798	.3118	.2417	.3324	.0413	.0485	.1841	.04	.0132	.0132	.0758	.0710	.0682	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000		.0758	
.1073	.1073	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-.3900	-.3900	-.3900									-.25	
.0413	.0413																											-.500		
																					1.0000									
																						1.0000								
																							1.0000							
																								1.0000						
																									1.0000					
																										1.0000				
																											1.0000			
																												1.0000	-1.0000	
																		-1.0000	-1.0000	-1.0000									-1.0000	1.0000

All values in million dollars, excapt Labour which is in thousands man years.

TABLE 4.2 Key to Rows of Table 4.1

1. Farming
2. Forestry
3. Forestry Processing
4. Hunting & Fishing
5. Mining
6. P.P.P.
7. Other Manufacturing
8. Building & Construction
9. Public Utilities
10. Transport & Communication
11. Distribution
12. Banking & Insurance
13. Services
14. Services to Households
15. Services to Government
16. Ownership (interindustry)
17. Ownership (final demand)
18. Farming Capital
19. Forest Capital
20. Forest Proc. Capital
21. H. & F. Capital
22. Mining Capital
23. P.P.P. Capital
24. Other Mfg. Capital
25. Building & Construction Capital
26. Public Utilities Capital
27. Transport & Communication Capital
28. Distribution Capital
29. Banking & Insurance Capital
30. Services Capital
31. Min. Government Investment
32. Ownership Capital
33. Min. Ownership Investment
34. Foreign Exchange
35. Savings
36. Labour
37. Max. Farming Exports
38. Max. Forestry Exports
39. Max. Forestry Proc. Exports
40. Max. H. & F. Exports
41. Max. Mining Exports
42. Max. P.P.P. Exports
43. Max. Other Manufacturing Exports
44. Min. Immigration Consumption
45. Total Consumption Reconcil.

CHAPTER V

THE LINEAR PROGRAMMING SOLUTION

5.1 The Optimum Solution

The linear programming model described in Chapter IV and depicted in Table 4.1, was solved on an IBM 1130 Computing System.[1] The particular numerical values chosen were thought to correspond most closely to the set of assumptions used in the projection work reported by Ross and Philpott [30], and hence to those thought appropriate by the Targets Committee to the National Development Conference [35].[2] This applies especially to the exporting limits used, many of the other assumptions of the projection study such as immigration and the rate of growth of consumption being endogenous in this study. The optimum solution should be useful, therefore, as a check on the structure projected by the Lincoln model for indicative planning. Conversely, the projected structure should be a check on the accuracy and usefulness of the linear programming model, for any wild fluctuations from the projected structure would be unlikely to represent a true optimum.

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[1] Some notes on computing problems encountered are given in Appendix II.

[2] A summary of the main assumptions of the model is given in Appendix III.

situation (in the sense that "optimum" is being used in this study.) Certainly, it is improbable that policies to achieve very radical structural changes could be successfully implemented by a central planning committee.

The values of the activities which maximise consumption in 1972-73 are given in Tables 5.1A to 5.1C; the shadow prices of the restrictions (the dual solution) are given in Tables 5.1D to 5.1F. The interindustry transactions matrix for the optimum structure (assuming that the same set of input-output coefficients are pertinent for 1972-73 as for 1964-65) is given in Table 5.2. To study the effects of some of the more arbitrary assumptions underlying the optimising model, some solutions with alternative assumptions were computed. Firstly, it must be admitted that the figure of $225 million for autonomous expenditure on housing (the minimum level set for activity P_{33}) was largely a guess, although it was chosen so that the total investment by "Ownership of Property" would be approximately the same as that calculated by the Lincoln model; a solution was therefore calculated with this figure at $350 million so that some idea of the seriousness of errors of this type to the overall solution might be ascertained. Secondly, the coefficients relating the target year investment flows to the target year capital stocks have been set at -6.6667 as a linear approximation to a 4.0 to 5.0 per cent annual increase in the levels of investment throughout the planning horizon;[1] solutions were obtained with these voefficients set at -8.0000 (representing constant levels of investment during the period and indicative of situations when the rate of growth of investment is low) and at -5.5555 (representing about 9.0 per cent annual increases in investment and indicative of situations

[1] See Appendix I.

TABLE 5.1A

Optimum Solution (Production Activities)

	Activity	Level($mn)	Shadow Price
P_1	Farming	1291.964	0.000
P_2	Forestry	59.352	0.000
P_3	Forestry Processing	349.875	0.000
P_4	Hunting & Fishing	9.475	0.000
P_5	Mining	61.098	0.000
P_6	Pri. Prod. Proc.	750.052	0.000
P_7	Other Manufacturing	2338.504	0.000
P_8	Building & Construction	876.252	0.000
P_9	Public Utilities	249.542	0.000
P_{10}	Transport & Communication	683.836	0.000
P_{11}	Distribution	1195.745	0.000
P_{12}	Banking & Insurance	217.477	0.000
P_{13}	Services	620.737	0.000
P_{14}	Services to Households	32.873	0.000
P_{15}	Services to Government	357.506	0.000
P_{16}	Ownership of Property (Interindustry)	92.924	0.000
P_{17}	Ownership of Property (final demand)	389.072	0.000

TABLE 5.1B

Optimum Solution (Net Investment Activities)

	Activity	Level($mn.)	Shadow Price
P_{18}	Farming	57.292	0.000
P_{19}	Forestry	5.206	0.000
P_{20}	Forestry Processing	3.750	0.000
P_{21}	Hunting & Fishing	0.000	1.081
P_{22}	Mining	2.415	0.000
P_{23}	Pri. Prod. Proc.	3.828	0.000
P_{24}	Other Manufacturing	41.315	0.000
P_{25}	Building & Construction	36.377	0.000
P_{26}	Public Utilities	66.565	0.000
P_{27}	Transport & Communication	56.014	0.000
P_{28}	Distribution	36.026	0.000
P_{29}	Banking & Insurance	12.929	0.000
P_{30}	Services	0.000	0.520
P_{31}	Government (autonomous)	228.000	0.000
P_{32}	Ownership of Property (interindustry)	32.157	0.000
P_{33}	Ownership of Property (autonomous)	225.000	0.000

TABLE 5.1C

Optimum Solution
(Consumption, Immigration, Exporting Activities)

	Activity	Level	Shadow Price
P_{34}	Consumption (no import substn.)	0.000	0.002
P_{35}	Consumption (5% import substn.)	4039.614	0.000
P_{36}	Consumption (10% import substn.)	0.000	0.002
P_{37}	Farming Exports	383.000	0.000
P_{38}	Forestry Exports	5.000	0.000
P_{39}	Forestry Proc. Exports	44.000	0.000
P_{40}	Hunting & Fishing Exports	0.000	0.278
P_{41}	Mining Exports	1.000	0.000
P_{42}	Pri. Prod. Proc. Exports	450.653	0.000
P_{43}	Other Mfg. Exports	212.000	0.000
P_{44}	Immigration ('000 people)	18.797	0.000
P_{45}	Immigrant Consumption	18.797	0.000
P_{46}	Total Consumption	4058.412	0.000

TABLE 5.1D

Optimal Solution (Shadow Prices of Restrictions)

	Restriction	Shadow Price	Amount in Disposal
R_1	Farming	1.026	0.000
R_2	Forestry	1.032	0.000
R_3	Forestry Proc.	.993	0.000
R_4	Hunting & Fishing	1.447	0.000
R_5	Mining	1.121	0.000
R_6	Pri. Prod. Proc.	1.133	0.000
R_7	Other Manufacturing	1.025	0.000
R_8	Building & Construction	1.212	0.000
R_9	Public Utilities	2.184	0.000
R_{10}	Transport & Communication	1.330	0.000
R_{11}	Distribution	.965	0.000
R_{12}	Banking & Insurance	.932	0.000
R_{13}	Services	1.388	0.000
R_{14}	Services to Households	.799	0.000
R_{15}	Services to Government	.799	0.000
R_{16}	Ownership of Property(interindustry)	2.221	0.000
R_{17}	Ownership of Property (final demand)	.484	0.000

TABLE 5.1E

Optimal Solution (Shadow prices of Restrictions)

	Restriction	Shadow Price	Amount in Disposal
R_{18}	Farming	0.162	0.000
R_{19}	Forestry	0.166	0.000
R_{20}	Forestry Proc.	0.180	0.000
R_{21}	Hunting & Fishing	0.000	2.720
R_{22}	Mining	0.169	0.000
R_{23}	Pri. Prod. Proc.	0.170	0.000
R_{24}	Other Manufacturing	0.174	0.000
R_{25}	Building & Construction	0.163	0.000
R_{26}	Public Utilities	0.171	0.000
R_{27}	Transport & Communication	0.170	0.000
R_{28}	Distribution	0.166	0.000
R_{29}	Banking & Insurance	0.179	0.000
R_{30}	Services	0.093	0.000
R_{31}	Government (autonomous)	1.186	0.000
R_{32}	Ownership of property	0.181	0.000
R_{33}	Ownership of property(autonomous)	1.208	0.000

TABLE 5.1F

Optimal Solution (Shadow Prices of Restrictions)

	Restriction	Shadow Price	Amount in Disposal
R_{34}	Foreign Exchange	1.141	0.000
R_{35}	Savings	0.000	399.324
R_{36}	Labour	2.782	0.000
R_{37}	Farming Exports	0.097	0.000
R_{38}	Forestry Exports	0.087	0.000
R_{39}	Forestry Proc. Exports	0.130	0.000
R_{40}	Hunting & Fishing Exports	0.000	10.000
R_{41}	Mining Exports	0.010	0.000
R_{42}	Pri. Prod. Proc. Exports	0.000	185.347
R_{43}	Other Mfg. Exports	0.099	0.000
R_{44}	Immigrants Consumption	0.931	0.000
R_{45}	Total Consumption	0.000	0.000

TABLE 5.2

OPTIMUM INPUT-OUTPUT TRANSACTIONS MATRIX 1972/73

	Farming	Forestry	Forestry Proc.	Hunting & Fishing	Mining	Pri. Prod. Proc.	Other Mfrg.	Bldg & Const.	Public Utilities	Trans. & Comm.	W/sale & Retail Trade	Bnkg & Ins.	Services	Services to H/holds	Services to Govt.	Ownership of Property	Total Intermed. Sales	Cons. & Govt.	Exports	Cap. Form'n	Total Output
Farming	251.5	-	-	.1	-	511.7	55.0	-	.2	.8	1.1	-	18.3	-	-	-	838.7	95.4	351.4	6.5	1292.0
Forestry	2.1	-	43.2	-	.1	.2	.2	.4	1.1	.2	.2	-	-	-	-	-	47.6	6.5	4.5	.7	59.4
Forestry Processing	13.0	.2	77.3	.1	-	11.6	63.6	82.7	1.4	3.2	25.9	1.9	4.5	-	-	4.8	290.2	10.1	40.8	8.2	349.9
Hunting & Fishing	.3	-	-	.1	-	.2	.5	-	-	.2	-	-	1.4	-	-	-	2.6	6.9	-	-	9.5
Mining	1.0	-	1.3	-	-	3.9	11.7	22.6	5.4	3.1	-	-	-	-	-	-	49.0	11.0	.9	.1	61.1
Pri. Prod. Proc.	3.2	-	-	-	-	48.2	14.7	-	-	1.1	2.9	-	18.6	-	-	-	88.7	243.5	417.8	-	750.1
Other Mfrg.	131.1	3.1	12.4	.9	2.5	17.5	334.2	131.6	9.7	94.4	52.6	10.2	53.2	-	-	18.8	872.4	1042.5	195.0	228.5	2338.5
Buildings & Construction	6.3	.7	1.8	.1	2.8	1.3	6.5	106.0	2.2	9.6	13.9	11.6	7.7	-	-	29.3	199.9	65.7	.2	610.6	876.2
Public Utilities	9.7	.2	6.3	.1	1.4	5.9	23.2	2.9	79.4	4.9	14.2	5.5	7.3	-	-	8.9	169.7	79.1	.7	-	249.5
Transport & Comm.	38.8	1.0	23.5	.4	11.0	21.8	120.2	39.6	6.1	79.4	52.5	12.6	20.4	-	-	3.5	430.8	172.5	48.5	32.1	683.8
W/sale & Retail Trade	60.3	1.0	18.4	.5	1.6	18.8	138.2	68.3	6.9	17.6	19.5	3.5	16.5	-	-	5.7	376.9	718.7	21.8	78.3	1195.7
Banking & Insurance	6.2	.5	3.8	.1	1.1	1.9	13.6	6.3	1.3	3.2	49.6	6.4	8.9	-	-	13.9	116.8	95.0	5.0	.7	217.5
Services	15.8	.8	3.7	.2	.8	2.1	35.8	8.2	.9	10.0	82.3	16.9	45.9	-	-	6.5	229.8	350.2	6.6	34.7	620.7
Services to Households	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32.9	-	-	32.9
Services to Government	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	357.5	-	-	357.5
Ownership of Property	-	.6	1.0	-	.1	.5	13.1	2.0	.4	3.1	38.7	5.4	23.9	-	-	8.4	97.3	382.3	2.4	-	482.0
Total Intermediate Purchases	539.4	8.0	192.8	2.5	21.4	645.2	830.4	470.7	115.1	230.9	253.5	74.1	226.6	-	-	99.6	3810.2	3669.8	1095.7	1000.5	9576.2
Imports	47.3	1.7	21.6	1.0	4.9	13.7	453.4	40.3	6.4	36.5	24.5	5.0	33.1	-	-	2.3	691.7	288.2		175.7	1155.6
Dep'n.	62.8	4.8	15.2	.3	7.7	10.5	62.9	19.1	21.6	40.8	43.9	14.3	18.4	-	-	51.7	718.6	-			374.0
Other	642.5	44.9	120.4	5.6	27.1	80.7	991.8	346.1	106.5	375.7	773.9	124.1	342.6	32.9	357.5	328.2	4700.3	100.3			4800.6
Total Inputs	1292.0	59.4	349.9	9.5	61.1	750.1	2338.5	876.2	249.5	683.8	1195.7	217.5	620.7	32.9	357.5	482.0	9920.9	4058.4	1095.7	1176.2	15906.5

All figures have been rounded to one decimal place.

TABLE 5.3A

Effect of Changes in Assumptions of Model
(Activity Levels)

Solution No.	1	2	3	4
	Control	Min. P_{33} \$350 m.	Capital-Inv. coeff. -5.5555	Capital-Inv. coeff. -8.000
P_1 Farming	1292	1279	1285	1504
P_2 Forestry	59	61	59	67
P_3 Forestry Proc.	350	363	350	402
P_4 Hunting & Fishing	9	9	9	11
P_5 Mining	61	64	61	71
P_6 P.P.P.	750	741	745	967
P_7 Other Mfg.	2338	2325	2324	2653
P_8 Bldg. & Construction	876	999	888	1059
P_9 Public Utilities	250	245	246	282
P_{10} Transp. & Communication	684	684	680	787
P_{11} Distribution	1196	1183	1183	1361
P_{12} Banking & Insurance	217	214	214	245
P_{13} Services	621	610	611	699
P_{14} Services to H/hold	33	32	32	36
P_{15} Services to Government	358	344	351	368
P_{16} Ownership(interindustry)	93	92	92	106
P_{17} Ownership (final demand)	389	375	380	430

TABLE 5.3B

Effect of Changes in Assumptions of Model
(Activity Levels)

Solution No.		1	2	3	4
		Control	Min. P_{33} \$350 m.	Capital-Inv. coeff. -5.5555	Capital-Inv. coeff. -8.000
P_{18}	Farm Investment	57	54	67	87
P_{19}	Forest. Investment	5	6	6	6
P_{20}	For. Proc. Inv.	4	4	5	5
P_{21}	H. & F. Inv.	-	-	-	-
P_{22}	Mining Inv.	2	3	3	3
P_{23}	P.P.P. Inv.	4	3	4	15
P_{24}	Other Mfg. Inv.	41	41	49	48
P_{25}	Bldg & Const. Inv.	36	64	47	65
P_{26}	Public Ut. Inv.	67	62	76	80
P_{27}	Transp. & Comm. Inv.	56	56	65	78
P_{28}	Distribution Inv.	36	35	42	45
P_{29}	Banking & Ins. Inv.	13	12	15	16
P_{30}	Services Inv.	-	-	-	39
P_{31}	Govt. Inv. (autonomous)	228	228	228	228
P_{32}	Ownership Inv.	32	32	30	123
P_{33}	Ownership Inv. (autonomous)	225	350	225	225

TABLE 5.3C

Effect of Changes in Assumptions of Model
(Activity Levels)

Solution No.		1	2	3	4
		Control	Min. P_{33} \$350 m.	Capital-Inv. coeff. -5.5555	Capital-Inv. coeff. -8.0000
P_{34}	Cons. (nil)	-	-	-	-
P_{35}	Cons. (5%)	4040	3889	3961	4155
P_{36}	Cons. (10%)	-	-	-	-
P_{37}	Farm. Exports	383	383	383	383
P_{38}	Forest. Exports	5	5	5	5
P_{39}	For. Proc. Exports	44	44	44	44
P_{40}	H. & F. Exports	-	-	-	-
P_{41}	Mining Exports	1	1	1	1
P_{42}	P. P. P. Exports	451	452	452	636
P_{43}	Other Mfg. Exports	212	212	212	212
P_{44}	Immigrants ('000)	19	21	-	335
P_{45}	Immigrants Cons.	19	21	-	335
P_{46}	Total Consumption	4058	3910	3961	4490
Total labour force		1140	1142	1131	1299
Total population		2988	2990	2969	3304
Cons/head (\$)		1358	1308	1334	1359

TABLE 5.3D

Effect of Changes in Assumptions of Model
(Shadow Prices)

Solution No.		1	2	3	4
		Control	Min. P_{33} \$350m.	Capital-Inv. coeff. -5.5555	Capital-Inv. coeff. -8.0000
R_1	Farming	1.026	1.026	1.065	.986
R_2	Forestry	1.032	1.032	1.067	.980
R_3	Forestry Proc.	.993	.993	1.005	.977
R_4	Hunting & Fishing	1.447	1.447	1.347	1.453
R_5	Mining	1.121	1.121	1.155	1.095
R_6	P.P.P.	1.133	1.133	1.172	1.093
R_7	Other Mfg.	1.025	1.025	1.021	1.048
R_8	Bldg. & Constr.	1.212	1.212	1.246	1.179
R_9	Public Utilities	2.184	2.184	2.513	1.980
R_{10}	Transp. & Comm.	1.330	1.330	1.393	1.284
R_{11}	Distribution	.965	.965	.966	.925
R_{12}	Bank. & Ins.	.932	.932	.998	.871
R_{13}	Services	1.388	1.388	1.299	1.384
R_{14}	Services to H/holds	.799	.799	.711	.788
R_{15}	Services to Govt.	.799	.799	.711	.788
R_{16}	Ownership(interind.)	2.221	2.221	2.618	1.891
R_{17}	Ownership(final dem.)	.484	.484	.482	.474

TABLE 5.3E

Effect of Changes in Assumptions of Model
(Shadow Prices)

Solution No.		1	2	3	4
		Control	Min. P_{33} \$350 m.	Capital-Inv. coeff. -5.5555	Capital-Inv. coeff. -8.0000
R_{18}	Farm. Cap.	.162	.162	.197	.138
R_{19}	Forest. Cap.	.166	.166	.202	.141
R_{20}	For. Proc. Cap.	.180	.180	.219	.154
R_{21}	H. & F. Cap.	-	-	-	-
R_{22}	Mining Cap.	.169	.169	.207	.143
R_{23}	P.P.P. Cap.	.170	.170	.209	.148
R_{24}	Other Mfg. Cap.	.174	.174	.212	.151
R_{25}	Bldg & Constr. Cap.	.163	.163	.199	.143
R_{26}	Publ. Util. Cap.	.171	.171	.209	.147
R_{27}	Tranp. & Comm. Cap.	.170	.170	.208	.149
R_{28}	Distribution Cap.	.166	.166	.201	.139
R_{29}	Bank. & Ins. Cap.	.179	.179	.220	.147
R_{30}	Services Cap.	.093	.093	-	.146
R_{31}	Govt. Inv. (autonomous)	1.186	1.186	1.218	1.166
R_{32}	Ownership Cap.	.181	.181	.223	.148
R_{33}	Ownership Inv. (auton.)	1.208	1.208	1.237	1.182

TABLE 5.3F

Effect of Changes in Assumptions of Model
(Shadow Prices)

Solution No.		1	2	3	4
		Control	Min. P_{33} \$350 m.	Capital-Inv. coeff. -5.5555	Capital-Inv. coeff. -8.0000
R_{34}	Foreign Exchange	1.141	1.141	1.181	1.351
R_{35}	Savings	-	-	-	-
R_{36}	Labour	2.782	2.782	2.475	2.746
R_{37}	Max. Farm. Exp.	.097	.097	.096	.348
R_{38}	Max. For. Exp.	.087	,087	.090	.348
R_{39}	Max. For. Proc. Exp.	.130	.130	.155	.357
R_{40}	Max. H. & F. Exp.	-	-	-	-
R_{41}	Max. Mining Exports	.010	.010	.014	.248
R_{42}	Max. P.P.P. Exports	-	-	-	.251
R_{43}	Max. Other Mfg. Exp.	.099	.099	.138	.291
R_{44}	Min. Imm. Cons.	.931	.931	.778	.953
R_{45}	Total Cons.	.000	.000	.000	.000

when it is difficult to achieve high levels of investment early in the planning period). The activity values of these extra solutions are compared with the original solution in Tables 5.3A to 5.3C and the shadow prices of the restrictions are compared in Tables 5.3D to 5.3F.

Before any comparisons or policy suggestions are made, the properties of the optimum solution warrant some attention.

5.1.1 Optimal Basis

The variables which comprise the optimal basis indicate that the model has behaved much as intended. Very few of the real activities have been excluded from the basis, and those which have (P_{21}, P_{30}, P_{34}, P_{36}, P_{40}) are either not considered to be crucial variables at this level of aggregation, or expected to be omitted due to the choices available.

5.1.2 Shadow Prices of Production Reconciliation Rows

The shadow prices of the production reconciliation rows are generally in the vicinity of unity, although they are perhaps not as close as one would have hoped.[1] In particular, the shadow prices of "Public Utilities" and "Ownership of Property (Interindustry)" are greater than 2.0. This could mean that these sectors are "bottlenecks" to economic development and that technological innovation would be of most benefit - at least marginally - if achieved in these areas. Nevertheless, the possibility that these values are the spurious consequences of anomolies in the parameters used should not be ruled out. This applies particularly to "Ownership of Property", which has been handled in a somewhat

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[1] See Chapter III, Sec. 3.5.

piecemeal fashion. The shadow prices for "Hunting and Fishing", "Building and Construction", "Transport and Communication", and "Services" are also slightly on the high side, but are not as disturbing. It is worth noting from Table 5.3D that Solution 4 (constant annual investment) has lower shadow prices for most of the restrictions on current production, although the values for "Public Utilities" and "Ownership of Property (Interindustry)" are still rather high.

Constraints R_{14}, R_{15} and R_{17} have been added to the model to force particular values into the solution, and the shadow prices of these constraints do not have any obvious economic interpretations.

5.1.3 Foreign Exchange, Labour, Savings

Foreign exchange and labour are both limiting resources but savings, as represented here, are not a "bottleneck" to the development of the New Zealand economy. The ratio of savings to consumption chosen was .39 which typifies a fairly high level of savings (28 per cent of gross national product). But assuming everything else is unaltered, this ratio can fall by $399.324 \div 4039.614 = .10$ to .29 (23 per cent of gross national product) before the calculated surplus is exhausted; it seems reasonable to conclude that savings should not be an impediment to economic growth in New Zealand.

In spite of the fairly high shadow price for labour, which supports the oft-voiced notion that New Zealand has a labour shortage, the optimum program prescribes very little immigration. This upholds the warning issued by the Monetary and Economic Council [23] that large scale immigration is not necessarily a solution to the labour shortage problem - especially if due attention is given to the additional strain on housing facilities and various social assets such as hospitals and schools.

Although foreign exchange is limiting its shadow price is much lower than labour's. This suggests that labour saving technologies should be foremost in the minds of economic strategists.

5.1.4 Shadow Prices of Capital Stock Reconciliation Rows

The shadow prices for the investment restrictions are approximately 16 to 18 per cent. These values might be interpreted as marginal productivities of capital, but the evidence of Table 5.3E (Solutions 3 and 4) shows that little confidence can be attached to these figures : when the annual rate of increase in investment levels is high the marginal productivity of capital is from 20 to 22 per cent; and when the rate is low the marginal productivity may be as low as 14 per cent. As there are few grounds for choosing one or another rate of growth of investment the true values of these shadow prices must remain open to doubt.

5.1.5 Import Substitution

The consumption activity chosen is that which has five per cent substitution of domestically manufactured final goods for imports. Foreign exchange is sufficiently scarce to warrant some import substitution, but it could not be called a high priority planning consideration. The shadow prices of the excluded consumption activities are extremely small (Table 5.1C) which means that the level of consumption (and consumption per head) would be only slightly smaller if one of these activities replaced the chosen consumption activity.

5.2 Comparison with N.D.C. Projections

The principal features of the proposed optimum economic structure for 1972-73 are set out in Table 5.4 for comparison with the structure projected by Ross and Philpott (Table 5.5). It is emphasised that this comparison should be very general.

TABLE 5.4

Economic Structure of N.Z. Economy 1972-73 : Linear Programming Model

	C + G	Exports	Capital Form'n	Total Output	Imports	Investment Net	Gross	Labour
1 Farming	95	351	7	1292	47	57	120	113
2 Forestry	6	4	1	59	2	5	10	9
3 Forestry Proc.	10	41	8	349	22	4	19	26
4 Hunting & Fishing	7	-	-	9	1	-	-	3
5 Mining	10	1	-	61	5	2	10	6
6 PPP	133	418	-	750	14	4	14	32
7 Other Mfg.	1043	195[1]	228	2338	453	41	104	262
8 Bldg & Constr.	66	-	611	876	40	36	55	94
9 Public Utilities	79	1	-	250	6	67	88	14
10 Transp. & Comm.	172	48[1]	32	684	37	56	97	97
11 Distn.	719	22	78	1196	25	36	80	166
12 Banking & Ins.	95	5	1	217	5	13	27	9
13 Services	350	7	35	621	33	-	18	178
14 Serv. to H/H	33	-	-	33	-	-	-	9
15 Serv. to Govt.	358	-	-	358	-	228	228	103
16 Ownership	382	2	-	389	2	257	307	19
Imports Cons.	288				288			
Cap.			178		178			
Other	100							
	4058	1095	1177		1155	806	1177	1140

[1] See note in Appendix III for an explanation of why these values differ markedly from the corresponding values in Table 5.5.

TABLE 5.5

Economic Structure of N.Z. Economy 1972-73 : Lincoln Projection Model

	C + G	Exports	Capital Form'n	Total Output	Imports	Investment (net)	Investment (gross)	Labour
1 Farming	74	351	41	1469	51	89	160	128
2 Forestry	6	4	1	60	2	4	9	9
3 Forestry Proc.	10	41	10	355	21	3	18	26
4 Hunting & Fishing	6	9	-	17	2	2	3	6
5 Mining	11	-	-	62	5	1	9	6
6 PPP	189	590	29	904	16	14	27	38
7 Other Mfg.	898	80	254	2184	404	26	85	245
8 Bldg & Constr.	67	-	670	936	41	68	88	100
9 Public Utilities	66	2	-	228	6	78	98	13
10 Transp. & Comm.	156	124	33	748	38	92	137	106
11 Distn.	566	53	119	1120	22	27	68	156
12 Banking & Ins.	79	13	1	203	4	8	21	27
13 Services	293	16	32	560	28	2	19)	
14 Serv. to H/H	27	-	-	27	-	-	-)	259
15 Serv. to Govt.	315	-	-	315	-	228	228)	
16 Ownership	355	6	-	451	2	217	265	incl. in banking
Imports Cons.	218				218			
Cap.			176		176			
Other	77	2						
	3414	1291	1364		1033	859	1234	1117

Source : Ross & Philpott[30], Table V.

Differences in the rationale and in some of the basic assumptions of the two studies mean that rigorous comparisons should not be made. A brief exposition of some of the differences is given in Appendix III.

5.2.1 Consumption

A much higher level of consumption is obtained in the linear programming solution than was assumed by Ross and Philpott. The difference is quite marked when considered as consumption per head : \$1358 per head for the optimisation model compared with \$1139 per head for the projection model. This suggests that a higher rate of growth can be achieved; although allowance should be made for imperfect knowledge throughout the economy, immobility within the labour force, the existence of specialised or non-substitutable capital, and the probable inapplicability of the assumed consumption pattern over a wide range of consumption levels; it is likely that the so-called optimum considerably over-states what is actually likely to be achieved.

5.2.2 Output Levels

The levels of output advocated for the productive sectors are similar for both studies except that there is a noticeable switch from "Farming" and "Primary Produce Processing" to "Other Manufacturing" in the linear programming solution. The implication is that manufacturing industries should play an increasingly important role in New Zealand's economic development.

5.2.3 Investment

Investment levels in the programming solution also reflect the need for substitution of "Other Manufacturing" for primary industries. In addition very low levels of investment (particularly net investment) are recommended for "Building and Construction", "Public Utilities", "Transport and Communication" and "Distribution". The programmed investment for these sectors in Solution 4 (Table 5.3B) is much closer to the projected investment, so that little importance should be afforded to the absolute levels suggested by the optimum solution. There is noticeably more agreement between the two studies concerning gross investment than net investment - a fact which generates doubts about the treatment of capital replacement, capital stocks and investment generally.

5.2.4 Exports, Imports, Labour

The patterns of exporting and importing differ little between the two studies, but not much scope for differences to reveal themselves has been allowed. The import coefficients and the maximum exporting limits used in the programming model are taken directly from the data and results of the Lincoln projection model. In spite of this the programmed solution exhibits a marked swing away from exports of processed primary products.

Labour use follows a similar pattern in each study, but the transfer of emphasis from primary industries to secondary manufacturing is again apparent.

5.2.5 Capital Formation

The capital formation attributed to each sector are little different. The rather large differences apparent for the "Farming", "Primary Produce Processing" and "Distribution" can be explained by the fact that in Table 5.5 changes in stocks are included in capital formation; stock changes have not been considered in the optimisation study.

5.3 Summary

The linear programming model has produced a plausible economic structure which should be useful for national economic planning in New Zealand. Likewise, it seems that the projection techniques used elsewhere should not seriously mislead planning organisations, although there is some evidence that a shift of resources out of farming into manufacturing industries would be to the long term advantage of New Zealand. However, Tables 5.3A to 5.3F demonstrate the danger of making definitive statements with respect to the absolute levels of the variables. The major use of the model should be to illustrate the consequences of changes in key parameters, and highlight parameters to which the solution is sensitive so that special efforts can be made to measure these parameters. Solutions 2, 3 and 4 of Tables 5.3A to 5.3F constitute an attempt at the latter use, and the comparison has shown that the assumed annual rate of growth of investment is of some importance. The relative levels of the variables for different parameter "settings" will be considered in the next chapter.

CHAPTER VI

DISCRETE VARIATIONS OF SOME PARAMETERS

6.1 Nature of Variations

It was inferred in Chapter V and shall be emphasised here that parametric changes and their effects on the optimum solution rather than the detailed examination of a solitary solution should be the main concern of planning bodies. Conventional parametric programming and sensitivity analysis do not constitute a major part of the analysis in this chapter as the solution is obviously "stable" in the sense that, due to restricted choice of activities, the optimal basis is not likely to alter very much. This would not be the case, of course, if more technological alternatives were included. But the possibility of large fluctuations in the values of the variables in the optimum solution still exists, and an exploration of this aspect ensues.

A list of the types of variations from the original specification follows:

(1) Variations in the terms of trade for primary products;

(2) Variations in the upper limits for exporting activities;

(3) Variations in the labour and capital requirements of some of the important sectors;

(4) Variations in the basic level of income necessary for immigrants;

(5) Variations in the housing capital requirements of immigrants.

6.2 Terms of Trade

In Chapter II it was intimated that fluctuating terms of trade for agricultural exports significantly affect the New Zealand economy. But the short term vagaries of export prices are difficult to predict and this study in no way accounts for such changes. Nevertheless, if reasonable projections of medium and long term trends in export prices can be obtained, the resultant changes in the guidelines for indicative planning can be investigated. To illustrate, the optimum structures were computed for a 20 per cent fall, over the planning period, in agricultural export prices and also for a 20 per cent rise in agricultural export prices. This is done by first lowering and then raising the coefficients for activities P_{37} and P_{42} in Row R_{34}. These solutions (Solutions 5 and 6) are compared with the original solution in Tables 6.1A to 6.1F.

There are a number of observations to be made from this exercise.

6.2.1 Vital Role of Agriculture[1]

The importance of allocating resources to "Farming" and "Primary Produce Processing" increases as the terms of trade for output from these sectors deteriorates. This is apparent from the current production levels (Table 6.1A) and the investment levels (Table 6.1B) programmed for these sectors. Similarly, when the prospects for agricultural export prices are bright, high levels of output and investment are advocated for farming and related industries. The effect on the level of consumption per head of the terms of trade is also quite graphic as can be seen in Table 6.1C. It seems fair to conclude that overseas prices for agricultural products are important indicators of the potential prosperity of New Zealand, but it is important to remember that when these prices are low expansion of primary production is still the most effective way of facing the crisis.

[1] This subsection should be interpreted cautiously. The reader's attention is drawn to Section 6.3 which demonstrates that the importance of agricultural production is diminished if rapid increases in markets for manufactured exports occur.

TABLE 6.1A

Effect of Changing Terms of Trade Primary Products
(Activity Levels)

Solution No.		5	1	6
Terms of Trade		0.8	1.0	1.2
P_1	Farming	1442	1292	1502
P_2	Forestry	59	59	63
P_3	Forestry Proc.	350	350	402
P_4	Hunting & Fishing	11	9	11
P_5	Mining	61	61	71
P_6	P.P.P.	913	750	969
P_7	Other Mfg.	2285	2338	2473
P_8	Bldg & Constr.	860	876	1098
P_9	Public Utilities	243	250	280
P_{10}	Transp. & Comm.	684	684	773
P_{11}	Distribution	1163	1196	1365
P_{12}	Banking & Ins.	210	217	244
P_{13}	Services	595	621	700
P_{14}	Services to H/hold	31	33	37
P_{15}	Services to Govt.	337	358	374
P_{16}	Ownership(interindustry)	91	93	104
P_{17}	Ownership(final dem.)	365	389	434

TABLE 6.1B

Effect of Changing Terms of Trade Primary Products
(Activity Levels)

Solution No.		5	1	6
Terms of Trade		.8	1.0	1.2
P_{18}	Farm Inv.	87	57	104
P_{19}	Forest. Inv.	5	5	6
P_{20}	For. Proc. Inv.	4	4	6
P_{21}	H. & F. Inv.	-	-	-
P_{22}	Mining Inv.	2	2	4
P_{23}	P. P. P. Inv.	14	4	18
P_{24}	Other Mfg. Inv.	39	41	48
P_{25}	Bldg & Constr. Inv.	33	36	87
P_{26}	Public Ut. Inv.	60	67	95
P_{27}	Transp. & Comm. Inv.	56	56	88
P_{28}	Distribution Inv.	32	36	55
P_{29}	Bank. & Ins. Inv.	11	13	19
P_{30}	Services Inv.	-	-	42
P_{31}	Govt. Inv. (autonomous)	228	228	228
P_{32}	Ownership Inv.	23	32	136
P_{33}	Ownership Inv. (autonomous)	225	225	225

TABLE 6.1C

Effect of Changing Terms of Trade Primary Products
(Activity Levels)

Solution No.		5	1	6
Terms of Trade		.8	1.0	1.2
P_{34}	Consumption (nil)	-	-	-
P_{35}	Consumption (5%)	3805	4040	4229
P_{36}	Consumption (10%)	-	-	-
P_{37}	Farm. Exports	383	383	383
P_{38}	Forest. Exports	5	5	-
P_{39}	For. Proc. Exports	44	44	44
P_{40}	H. & F. Exports	2	-	-
P_{41}	Mining Exports	1	1	-
P_{42}	P.P.P. Exports	632	451	636
P_{43}	Other Mfg Exports	212	212	-
P_{44}	Imm. ('000)	-	19	303
P_{45}	Imm. Cons.	-	19	303
P_{46}	Total Cons.	3805	4058	4531
Total labour force		1131	1140	1283
Total population		2969	2988	3272
Cons/head		1282	1358	1385

TABLE 6.1D

Effect of Changing Terms of Trade Primary Products
(Shadow Prices)

Solution No.		5	1	6
Terms of Trade		.8	1.0	1.2
R_1	Farming	1.020	1.026	1.028
R_2	Forestry	1.009	1.032	1.040
R_3	Forestry Proc.	.998	.993	.994
R_4	Hunting & Fishing	1.446	1.447	1.480
R_5	Mining	1.126	1.121	1.118
R_6	P. P. P.	1.126	1.133	1.135
R_7	Other Mfg.	1.048	1.025	1.015
R_8	Bldg & Constr.	1.211	1.212	1.211
R_9	Public Utilities	2.271	2.184	2.146
R_{10}	Transp. & Comm.	1.341	1.330	1.324
R_{11}	Distribution	.921	.965	.982
R_{12}	Bank. & Ins.	.924	.932	.935
R_{13}	Services	1.283	1.388	1.439
R_{14}	Serv. to H/hold.	.705	.799	.836
R_{15}	Serv. to Govt.	.705	.799	.836
R_{16}	Ownership(interind.)	2.210	2.221	2.225
R_{17}	Ownership(final dem.)	.472	.484	.488

TABLE 6.1E

Effect of Changing Terms of Trade Primary Products
(Shadow Prices)

Solution No.		5	1	6
Terms of Trade		.8	1.0	1.2
R_{18}	Farm. Cap.	.169	.162	.159
R_{19}	Forest. Cap.	.173	.166	.163
R_{20}	For. Proc. Cap.	.188	.180	.178
R_{21}	H. & F. Cap.	.044	-	-
R_{22}	Mining Cap.	.175	.169	.167
R_{23}	P.P.P. Cap.	.182	.170	.166
R_{24}	Other Mfg Cap.	.184	.174	.170
R_{25}	Bldg & Constr. Cap.	.175	.163	.157
R_{26}	Publ. Util. Cap.	.181	.171	.167
R_{27}	Transp. & Comm. Cap.	.184	.170	.164
R_{28}	Distribution Cap.	.168	.166	.165
R_{29}	Bank. & Ins. Cap.	.181	.179	.178
R_{30}	Services Cap.	-	.093	.167
R_{31}	Govt. Inv. (autonomous)	1.197	1.186	1.180
R_{32}	Ownership Cap.	.181	.181	.181
R_{33}	Ownership Inv. (autonomous)	1.208	1.208	1.207

TABLE 6.1F

Effect of Changing Terms of Trade Primary Products
(Shadow Prices)

Solution No.		5	1	6
Terms of Trade		0.8	1.0	1.2
R_{34}	Foreign Exchange	1.417	1.141	1.026
R_{35}	Savings	-	-	-
R_{36}	Labour	2.456	2.782	2.912
R_{37}	Max. Farm Exp.	.097	.097	.186
R_{38}	Max. For. Exp.	.385	.087	-
R_{39}	Max. For. Proc. Exp.	.411	.130	.014
R_{40}	Max. H. & F. Exp.	-	-	-
R_{41}	Max. Mining Exp.	.283	.010	-
R_{42}	Max P. P. P. Exp.	-	-	.088
R_{43}	Max. Oth. Mfg. Exp.	.354	.099	-
R_{44}	Min. Imm. Cons.	.854	.931	.927
R_{45}	Total Cons.	-	-	-

6.2.2 Foreign Exchange and Labour Scarcity

Unlike savings, foreign exchange and labour have been shown to be factors which limit growth in the New Zealand economy. Labour scarcity dominates foreign exchange scarcity as its shadow price is nearly $2\frac{1}{2}$ times greater, but it is manifest from Table 6.1F that the shadow price of the foreign exchange restriction increases and that of the labour restriction decreases as the terms of trade for primary products declines.

The effect on the opportunity costs of the restrictions on the levels of individual exports is also interesting. As expected, they tend to rise as foreign exchange becomes relatively more scarce - especially for forestry products and manufactured goods. At the same time the shadow prices for exports from "Farming" and from "Primary Produce Processing" do not show signs of increasing : if the long term prospects in agricultural prices are poor, the increase in farming output should continue, but the greatest marginal benefit to the economy will come from the expansion of export outlets in manufacturing and forestry.

6.3 Upper Limits on Exporting Activities

Irrespective of export prices, uncertainty often exists as to the scope or size of future markets for some products. Often the limits are determined politically - the possibility of the United Kingdom joining the European Economic Community being an example that could affect New Zealand's main market for dairy products - and can only be treated in a trial and error fashion in a study such as this. The export limits used for the optimisation reported in Chapter V correspond to those projected by Ross and Philpott [30] and are therefore in line with the targets used by the National Development Conference (assuming 1964-65 export prices). The likely consequences of changes

TABLE 6.2A Effect of Varying Export Limits (Activity Levels)

Solution No.		1	7	8	9	10	11	12
Max. exports		Control	All x 2	Farming x 2	Mfg x 2	Farming x $\frac{1}{2}$	PPP x $\frac{1}{2}$	Mfg x $\frac{1}{2}$
P_1	Farming	1292	1181	1417	1139	1223	1145	1361
P_2	Forestry	59	60	59	59	59	55	60
P_3	Forestry Proc.	350	398	347	348	352	321	351
P_4	Hunt. & Fishing	9	9	9	9	9	17	9
P_5	Mining	61	59	59	60	62	56	61
P_6	P.P.P.	750	306	379	565	928	598	834
P_7	Other Mfg.	2338	2535	2360	2526	2343	2160	2259
P_8	Bldg & Constr.	876	876	880	872	878	800	879
P_9	Public Utilities	250	248	248	249	250	230	250
P_{10}	Transp. & Comm.	684	683	681	683	685	622	684
P_{11}	Distribution	1196	1194	1207	1191	1191	1094	1197
P_{12}	Bank. & Ins.	217	218	218	218	217	201	217
P_{13}	Services	621	627	624	624	618	574	619
P_{14}	Serv. to H/hold.	33	33	33	33	33	31	33
P_{15}	Serv. to Govt.	358	359	359	359	356	335	356
P_{16}	Ownership(interind.)	93	94	93	94	93	85	92
P_{17}	Ownership(final dem.)	389	391	390	390	387	363	388

TABLE 6.2B Effect of Varying Export Limits (Activity Levels)

Solution No.	1	7	8	9	10	11	12
Max. exports	Control	All x 2	Farming x 2	Mfg x 2	Farming x $\frac{1}{2}$	PPP x $\frac{1}{2}$	Mfg x $\frac{1}{2}$
P_{18} Farm Inv.	57	32	85	23	42	24	71
P_{19} Forest. Inv.	5	6	5	5	5	4	5
P_{20} For. Proc. Inv.	4	6	3	4	4	2	4
P_{21} H. & F. Inv.	-	-	-	-	-	2	-
P_{22} Mining Inv.	2	2	2	2	3	2	2
P_{23} P. P. P. Inv.	4	-	-	-	15	-	9
P_{24} Other Mfg. Inv.	41	52	42	51	42	32	37
P_{25} Bldg. & Const. Inv.	36	36	37	35	37	19	37
P_{26} Publ. Ut. Inv.	67	65	65	66	67	48	67
P_{27} Transp. & Comm. Inv.	56	56	55	56	56	34	53
P_{28} Distribution Inv.	36	36	37	35	35	25	36
P_{29} Bank. & Ins. Inv.	13	13	13	13	13	9	13
P_{30} Services Inv.	-	-	-	-	-	-	-
P_{31} Govt. Inv. (autonomous)	228	228	228	228	228	228	228
P_{32} Ownership Inv.	32	34	32	33	32	16	32
P_{33} Ownership Inv. (autonomous)	225	225	225	225	225	225	225

TABLE 6.2C Effect of Varying Export Limits (Activity Levels)

Solution No. / Max. exports		Control	All x 2	Farming x 2	Mfg x 2	Farming x 2	PPP x ½	Mfg x ½
P_{34}	Cons. (nil)	-	-	-	-	-	-	-
P_{35}	Cons. (5%)	4040	4060	4054	4051	-	-	-
P_{36}	Cons. (10%)	-	-	-	-	4018	3785	4026
P_{37}	Farm. Exports	383	612	766	383	192	383	383
P_{38}	Forest. Exports	5	-	5	5	5	5	5
P_{39}	For. Proc. Exports	44	88	44	44	44	44	44
P_{40}	H. & F. Exports	-	-	-	-	-	10	-
P_{41}	Mining Exports	1	-	-	-	1	1	1
P_{42}	P. P. P. Exports	451	-	74	262	632	318	537
P_{43}	Other Mfg Exports	212	424	212	424	212	212	106
P_{44}	Imm. ('000)	19	17	18	18	19	-	19
P_{45}	Imm. Cons.	19	17	18	18	19	-	19
P_{46}	Total Cons.	4058	4077	4072	4069	4038	3785	4046
Total Labour Force		1140	1139	1140	1140	1140	1131	1140
Total Population		2988	2986	2987	2987	2988	2969	2988
Cons./head ($)		1358	1365	1363	1363	1351	1275	1354

TABLE 6.2D Effect of Varying Export Limits (Shadow Prices)

Solution No.		1	7	8	9	10	11	12
Max. exports		Control	All x 2	Farming x 2	Mfg x 2	Farming x 2	PPP x $\frac{1}{2}$	Mfg x $\frac{1}{2}$
R_1	Farming	1.026	1.032	1.032	1.032	1.025	.970	1.025
R_2	Forestry	1.032	1.044	1.042	1.042	1.031	.834	1.031
R_3	Forestry Proc.	.993	.998	.998	.998	.992	.955	.992
R_4	Hunting & Fishing	1.447	1.482	1.472	1.472	1.446	1.139	1.446
R_5	Mining	1.121	1.124	1.124	1.124	1.120	1.161	1.120
R_6	P.P.P.	1.133	1.064	1.063	1.063	1.132	.949	1.132
R_7	Other Mfg.	1.025	1.021	1.023	1.023	1.024	1.218	1.024
R_8	Bldg. & Constr.	1.212	1.217	1.217	1.217	1.211	1.202	1.211
R_9	Publ. Utilities	2.184	2.162	2.171	2.171	2.182	2.916	2.182
R_{10}	Transp. & Comm.	1.330	1.331	1.332	1.332	1.329	1.422	1.329
R_{11}	Distribution	.965	.984	.980	.980	.964	.604	.964
R_{12}	Bank. & Ins.	.932	.939	.938	.938	.931	.875	.931
R_{13}	Services	1.388	1.437	1.425	1.425	1.388	.663	1.388
R_{14}	Serv. to H/hold.	.799	.834	.826	.826	.798	-	.798
R_{15}	Serv. to Govt.	.799	.834	.826	.826	.798	-	.798
R_{16}	Ownership(interind.)	2.221	2.235	2.234	2.234	2.220	2.131	2.220
R_{17}	Ownership(final dem.)	.484	.490	.489	.489	.483	.387	.483

TABLE 6.2E Effect of Varying Export Limits (Shadow Prices)

Solution No.		1	7	8	9	10	11	12
Max. exports		Control	All x 2	Farming x 2	Mfg x 2	Farming x 2	PPP x $\frac{1}{2}$	Mfg x $\frac{1}{2}$
R_{18}	Farm. Cap.	.162	.160	.161	.161	.162	.221	.162
R_{19}	Forest. Cap.	.166	.164	.165	.165	.166	.225	.166
R_{20}	For. Proc. Cap.	.180	.178	.179	.179	.180	.252	.180
R_{21}	H. & F. Cap.	-	-	-	-	-	.215	-
R_{22}	Mining Cap.	.169	.168	.168	.168	.169	.217	.169
R_{23}	P. P. P. Cap.	.170	-	-	-	.170	-	.170
R_{24}	Other Mfg. Cap.	.174	.171	.172	.172	.174	.262	.174
R_{25}	Bldg. & Constr. Cap.	.163	.159	.160	.160	.163	.273	.163
R_{26}	Publ. Util. Cap.	.171	.168	.169	.169	.171	.258	.171
R_{27}	Transp. & Comm. Cap.	.170	.166	.167	.167	.170	.287	.170
R_{28}	Distribution Cap.	.166	.166	.166	.166	.166	.185	.166
R_{29}	Bank. & Ins. Cap.	.179	.179	.179	.179	.179	.194	.179
R_{30}	Services Cap.	.093	.161	.144	.144	.093	-	.093
R_{31}	Govt. Inv. (autonomous)	1.186	1.187	1.188	1.188	1.185	1.277	1.185
R_{32}	Ownership Cap.	.181	.182	.182	.182	.181	.182	.181
R_{33}	Ownership Inv. (autonomous)	1.208	1.213	1.213	1.213	1.207	1.213	1.207

TABLE 6.2F Effect of Varying Export Limits (Shadow Prices)

Solution No.		1	7	8	9	10	11	12
Max. exports		Control	All x 2	Farming x 2	Mfg x 2	Farming x 2	PPP x ½	Mfg x ½
R_{34}	Foreign Exch.	1.141	1.050	1.077	1.077	1.141	3.462	1.141
R_{35}	Savings	-	-	-	-	-	-	
R_{36}	Labour	2.782	2.905	2.876	2.876	2.780	-*	2.780
R_{37}	Max. Farm. Exp.	.097	-	.027	.027	.097	2.477	.097
R_{38}	Max. For. Exp.	.087	-	.013	.013	.087	2.595	.087
R_{39}	Max. For. Proc. Exp.	.130	.033	.060	.060	.130	2.493	.130
R_{40}	Max. H. & F. Exp.	-	-	-	-	-	2.320	-
R_{41}	Max. Mining Exp.	.010	-	-	-	.010	2.301	.010
R_{42}	Max. P. P. P. Exp.	-	-	-	-	-	2.498	-
R_{43}	Max. Oth. Mfg. Exp.	.098	.011	.035	.035	.098	2.249	.098
R_{44}	Min. Imm. Cons.	.931	.927	.928	.928	.930	1.017	.930
R_{45}	Total Cons.	-	-	-	-	-	-	-

* 85.3 thousand labour units (man-years) in disposal.

in these limits were investigated by either doubling or halving the limits for the more important export categories - "Farming" exports (mainly wool), "Primary Produce Processing" exports (meat and dairy products, processed vegetables) and "Other Manufacturing" exports. The results are given in Tables 6.2A to 6.2F (Solutions 7 to 12). It is of course very unlikely that changes in the size of markets would be so large, but, as stated in Chapter I, such analysis is worthwhile if some features of cause and effect within the economic system are revealed.

6.3.1 All Export Limits Doubled

When exports are "unchained" as for Solution 7 there is a distinct movement away from primary exports - especially processed primary exports. The level of output for "Primary Produce Processing" is very small, the levels of investment for "Farming" and "Primary Produce Processing" are also low, and the level of processed primary exports is programmed to be zero (Tables 6.2A, 6.2B, 6.2C). Processed forestry exports and secondary manufactured exports are the only exporting activities which enter the solution at the maximum level (Table 6.2F). The shadow price for labour is rather high, but the solution does not recommend a large amount of immigration.

6.3.2 Some Export Limits Doubled

Solutions 8 and 9 show the effects of doubling the maximum limits for "Farming" exports and "Other Manufacturing" exports respectively.[1] These solutions are very similar (they have exactly

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[1] In Solution 1, processed primary exports do not enter at the maximum level so there was no point in increasing this limit.

the same dual solution - i.e., the optimal bases have the same composition). The only real difference is the expected one : Solution 8 has high levels of output and investment in "Farming" whereas Solution 9 has high levels of output and investment in "Other Manufacturing". It is interesting to note that Solution 9 (representative of rapidly expanding markets for manufactured goods) has a much higher level (although still very low) of output and exporting of processed primary products than Solution 8. This suggests that there is something of a complementary effect between "Other Manufacturing" and "Primary Produce Processing". However, it should be remembered that in Solution 9 "Farming" exports are restricted whereas in Solution 8 they are not. The higher level of "Primary Produce Processing" in Solution 9 is more likely a substitution effect to replace the export income lost by restricting "Farming" exports.

6.3.3 Some Export Limits Halved

As the outlook for New Zealand's markets has recently been more pessimistic than optimistic, optimal solutions with half the export potential for "Farming", "Primary Produce Processing", and "Other Manufacturing" were obtained; these are Solutions 10, 11 and 12.

The already observed substitution between "Farming", "Primary Produce Processing" and "Other Manufacturing" is again apparent. The phenomenon of complementarity between "Primary Produce Processing" and "Other Manufacturing" is also discernible from Solutions 11 and 12; in fact, the levels of output and investment for "Other Manufacturing" are lower when "Primary Produce Processing" exports are restricted than when "Other Manufacturing" exports are restricted. In all three of these solutions the consumption activity with the greatest amount of import substitution is chosen.

However, the most striking feature of the comparison is the severity with which restriction of exports of processed primary products affects the economy (Solution 11). Apart from the substitution effect mentioned earlier, the relative importance of each sector is similar to other solutions, but the absolute levels of output and investment are pared down to the extent that labour is no longer a scarce resource. In fact there are 85,300 surplus labour units (man years) in the optimum solution. The shadow prices of foreign exchange and each of the restrictions on export levels are very high (Table 6.2F) and consumption per head is very low (Table 6.2C). The implication is that New Zealand's economic prosperity (measured by the level of employment and consumption per head) is extremely dependent on the maintenance of markets for processed primary products. This is somewhat disturbing as dairy products constitute a major portion of these exports and the markets for these are anything but secure. At the same time, the results of Solutions 7, 8 and 9 should not be forgotten; that these products do not play an important role if all other markets are expanding. Also, processed primary products include meat for which markets appear favourable. It would be helpful if the analysis could be repeated with a disaggregated "Primary Produce Processing" sector.[1]

It seems reasonable to conclude that serious efforts should be made to maintain the dairy market - at least in the short term. However, evidence also exists that expansion of other markets (processed forestry products and manufactured goods in particular) could be a more positive approach to economic policy.

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[1] As noted in Chapter II, this will soon be possible due to the disaggregation of the Lincoln model by Professor B.J. Ross.

6.4 Technological Change

The measurement of technological change is currently one of the most urgent needs of economic science. Technology can be thought of as "way of using" capital, labour or any other primary resource. If the same input of capital or labour, ceteris paribus, can be used so that greater output is achieved, a technological change has occurred. The present model has taken some account of this by assuming a reduction in the labour-output ratios during the planning period. As a possible guide to the allocation of research expenditure both the capital-output and labour-output ratios were reduced for "Farming", "Processed Primary Products" and "Other Manufacturing" in turn. It was hoped that the relative impact of technology on these sectors would indicate in which sectors technological change would be of most benefit to the economy as a whole. Solutions 13, 14 and 15 are set out in Tables 6.3A to 6.3F, and some comments on them follow.

Firstly, in terms of consumption per head, technological change is of most benefit when achieved in the "Other Manufacturing" sector, but it is only slightly less beneficial when achieved in "Farming" (Table 6.3C).

The effects on output levels seem to differ little (Table 6.3A). The most noticeable differences are in the programmed investment levels (Table 6.3B): the level of investment to maintain production does not need to be as high for the sector in which the technological change has taken place. This may not be of major importance as total investment is restricted only by foreign exchange - not by the availability of savings. Nevertheless, it could take some strain off the mechanisms for financing investment, a possible bottleneck which is not accounted for in the model.

TABLE 6.3A

Possible Effects of Technological Change
(Activity Levels)

Solution No.	1	13	14	15
10% Tech. Change	Control	Farming	PPP	Other Mfg.
P_1 Farming	1292	1304	1296	1325
P_2 Forestry	59	60	59	60
P_3 Forestry Proc.	350	351	351	357
P_4 Hunting & Fishing	9	10	10	10
P_5 Mining	61	61	60	62
P_6 P.P.P.	750	763	754	783
P_7 Other Mfg.	2338	2354	2344	2389
P_8 Bldg & Constr.	876	879	877	889
P_9 Public Utilities	250	252	250	255
P_{10} Transp. & Comm.	684	689	685	700
P_{11} Distribution	1196	1206	1199	1223
P_{12} Bank. & Ins.	217	220	218	222
P_{13} Services	621	629	623	633
P_{14} Serv. to H/hold.	33	33	33	34
P_{15} Serv. to Govt.	358	363	359	365
P_{16} Ownership(interind.)	93	94	93	95
P_{17} Ownership(final dem.)	389	395	390	397

TABLE 6.3B

Possible Effects of Technological Change
(Activity Levels)

Solution No.		1	13	14	15
10% Tech. Change		None	Farming	PPP	Mfg.
P_{18}	Farm Inv.	57	31	58	65
P_{19}	Forest. Inv.	5	5	5	6
P_{20}	For. Proc. Inv.	4	4	4	4
P_{21}	H. & F. Inv.	-	-	-	-
P_{22}	Mining Inv.	2	2	2	3
P_{23}	P. P. P. Inv.	4	5	-	6
P_{24}	Other Mfg. Inv.	41	42	42	31
P_{25}	Bldg. & Const. Inv.	36	36	36	39
P_{26}	Publ. Ut. Inv.	67	69	67	72
P_{27}	Trans. & Comm. Inv.	56	58	57	62
P_{28}	Distribution Inv.	36	37	36	39
P_{29}	Bank. & Ins. Inv.	13	13	13	14
P_{30}	Services Inv.	-	-	-	-
P_{31}	Govt. Inv. (autonomous)	228	228	228	228
P_{32}	Ownership Inv.	32	33	32	34
P_{33}	Ownership Inv. (autonomous)	225	225	225	225

TABLE 6.3C

Possible Effects of Technological Change
(Activity Levels)

Solution No.		1	13	14	15
10% Tech. Change		None	Farming	PPP	Mfg
P_{34}	Cons. (nil)	-	-	-	-
P_{35}	Cons. (5%)	4040	4103	4053	4129
P_{36}	Cons. (10%)	-	-	-	-
P_{37}	Farm. Exports	383	383	383	383
P_{38}	Forest. Exports	5	5	5	5
P_{39}	For. Proc. Exports	44	44	44	44
P_{40}	H. & F. Exports	-	-	-	-
P_{41}	Mining Exports	1	-	-	1
P_{42}	P. P. P. Exports	451	459	454	477
P_{43}	Other Mfg. Exports	212	212	212	212
P_{44}	Imm. ('000)	19	17	18	16
P_{45}	Imm. Cons.	19	17	18	16
P_{46}	Total Cons.	4058	4120	4071	4144
Total labour force		1140	1139	1140	1139
Total population		2988	2986	2987	2985
Cons/head ($)		1358	1380	1363	1388

TABLE 6.3D

Possible Effects of Technological Change
(Shadow Prices)

Solution No.		1	13	14	15
10% Tech. Change		None	Farming	PPP	Mfg
R_1	Farming	1.026	.969	1.033	1.029
R_2	Forestry	1.032	1.040	1.043	1.041
R_3	Forestry Proc.	.993	.998	.999	1.002
R_4	Hunting & Fishing	1.447	1.446	1.479	1.471
R_5	Mining	1.121	1.125	1.125	1.128
R_6	P.P.P.	1.133	1.094	1.051	1.138
R_7	Other Mfg.	1.025	1.024	1.023	.994
R_8	Bldg. & Constr.	1.212	1.217	1.218	1.216
R_9	Public Utilities	2.184	2.180	2.169	2.185
R_{10}	Transp. & Comm.	1.330	1.334	1.333	1.337
R_{11}	Distribution	.965	.975	.982	.975
R_{12}	Bank. & Ins.	.932	.937	.939	.938
R_{13}	Services	1.388	1.412	1.432	1.419
R_{14}	Serv. to H/hold.	.799	.817	.830	.819
R_{15}	Serv. to Govt.	.799	.817	.830	.819
R_{16}	Ownership(interind.)	2.221	2.233	2.236	2.231
R_{17}	Ownership(final dem.)	.484	.488	.490	.487

TABLE 6.3E

Possible Effects of Technological Change
(Shadow Prices)

Solution No.		1	13	14	15
10% Tech. Change		None	Farming	PPP	Mfg.
R_{18}	Farm. Cap.	.162	.161	.160	.160
R_{19}	Forest. Cap.	.166	.165	.164	.165
R_{20}	For. Proc. Cap.	.180	.180	.179	.181
R_{21}	H. & F. Cap.	-	-	-	-
R_{22}	Mining Cap.	.169	.169	.168	.169
R_{23}	P. P. P. Cap.	.170	.169	-	.170
R_{24}	Other Mfg. Cap.	.174	.173	.172	.174
R_{25}	Bldg. & Constr. Cap.	.163	.162	.160	.162
R_{26}	Publ. Util. Cap.	.171	.170	.169	.171
R_{27}	Trans. & Comm. Cap.	.170	.168	.167	.169
R_{28}	Distribution Cap.	.166	.166	.166	.165
R_{29}	Bank. & Ins. Cap.	.179	.179	.179	.179
R_{30}	Services Cap.	.093	.127	.153	.131
R_{31}	Govt. Inv. (autonomous)	1.186	1.189	1.189	1.189
R_{32}	Ownership Cap.	.181	.182	.182	.182
R_{33}	Ownership Inv. (autonomous)	1.208	1.213	1.214	1.212

TABLE 6.3F

Possible Effects of Technological Change
(Shadow Prices)

Solution No.		1	13	14	15
10% Tech. Change		None	Farming	PPP	Mfg.
R_{34}	Foreign Exchange	1.141	1.105	1.066	1.147
R_{35}	Savings	-	-	-	-
R_{36}	Labour	2.782	2.845	2.891	2.853
R_{37}	Max. Farm Exp.	.097	.113	.015	.099
R_{38}	Max. For. Exp.	.087	.043	-	.083
R_{39}	Max. For. Proc. Exp.	.130	.089	.048	.125
R_{40}	Max. H. & F. Exp.	-	-	-	-
R_{41}	Max. Mining Exp.	.010	-	-	.009
R_{42}	Max. P. P. P. Exp.	-	-	-	-
R_{43}	Max. Oth. Mfg. Exp.	.099	.063	.024	.132
R_{44}	Min. Imm. Cons.	.931	.929	.928	.929
R_{45}	Total Cons.	.000	.000	.000	.000

Thirdly, the shadow prices for foreign exchange and labour (Table 6.3F) indicate that technological change tends to amplify the labour shortage problem. For the "Farming" and "Other Manufacturing" sectors the shadow prices of the restrictions on export levels fall (although only slightly when the technological change is in the "Other Manufacturing" sector) except for the sector in which the technological change has occurred. This could mean that policies which encourage technological change in these sectors will be of limited use unless simultaneously matched by policies to expand export markets for the same sectors.

6.5 Consumption for Immigrants

The consumption activity for immigrants has been mooted as an approximation to optimising consumption per head. As a means of evaluating the effectiveness of the ploy, a number of solutions were obtained in which the consumption requirements of a unit of immigration (1000 people) was reduced. These are Solutions 16 to 19 set out in Tables 6.4A to 6.4F.

As soon as the coefficient is reduced from 1.0 to 0.9 the levels of output and investment rise considerably (Tables 6.4A and 6.4B), but thereafter they change very little. Total consumption rises only slightly and the level of immigration steadily increases. The result is that consumption per head gradually decreases (Table 6.4C). The model appears to behave in such a way that, once the first increase in activity has taken place, substitution between immigrants' consumption and indigenous consumption occurs and all the other variables remain at about the same levels.

TABLE 6.4A

Effect of Lowering Immigrants' Consumption Requirements
(Activity Levels)

Solution No.		1	16	17	18	19
Min. cons. ($mn/'000)		1.0	0.9	0.8	0.5	0.0
P_1	Farming	1292	1490	1490	1492	1492
P_2	Forestry	59	68	68	68	68
P_3	Forestry Proc.	350	407	407	410	411
P_4	Hunt. & Fish.	9	10	10	19	19
P_5	Mining	61	72	72	72	72
P_6	P.P.P.	750	956	956	957	957
P_7	Other Mfg.	2338	2657	2657	2674	2675
P_8	Bldg. & Constr.	876	1101	1102	1117	1121
P_9	Pub. Ut.	250	276	276	277	277
P_{10}	Transp. & Comm.	684	784	784	789	790
P_{11}	Distribution	1196	1345	1345	1352	1352
P_{12}	Bank. & Ins.	217	240	240	241	241
P_{13}	Services	621	685	685	688	688
P_{14}	Serv. to H/hold.	33	35	35	35	35
P_{15}	Serv. to Govt.	358	358	361	369	383
P_{16}	Ownership(interind.)	93	105	105	105	105
P_{17}	Ownership(final dem.)	389	415	415	416	416

TABLE 6.4B

Effect of Lowering Immigrants' Consumption Requirements
(Activity Levels)

Solution No.	1	16	17	18	19
Min. cons. ($mn/'000)	1.0	0.9	0.8	0.5	0.0
P_{18} Farm. Inv.	57	102	102	102	102
P_{19} Forest. Inv.	5	8	8	8	8
P_{20} For. Proc. Inv.	4	7	7	7	7
P_{21} H. & F. Inv.	-	-	-	2	2
P_{22} Mining Inv.	2	4	4	4	4
P_{23} P. P. P. Inv.	4	17	17	17	17
P_{24} Other Mfg Inv.	41	58	58	59	59
P_{25} Bldg. & Const. Inv.	36	88	88	91	92
P_{26} Publ. Ut. Inv.	67	91	91	92	92
P_{27} Trans. & Comm. Inv.	56	92	92	94	94
P_{28} Distribution Inv.	36	53	53	54	54
P_{29} Bank. & Ins. Inv.	13	18	18	18	18
P_{30} Services Inv.	-	44	44	48	49
P_{31} Govt. Inv. (autonomous)	228	228	228	228	228
P_{32} Ownership Inv.	32	141	142	151	154
P_{33} Ownership Inv. (autonomous)	225	225	225	225	225

TABLE 6.4C

Effect of Lowering Immigrants' Consumption Requirements
(Activity Levels)

Solution No.	1	16	17	18	19
Min. cons. ($mn/'000)	1.0	0.9	0.8	0.5	0.0
P_{34} Cons. (nil)	-	-	-	-	-
P_{35} Cons. (5%)	4040	-	-	-	-
P_{36} Cons. (10%)	-	4044	4074	4168	4338
P_{37} Farm. Exports	383	383	383	383	383
P_{38} Forest. Exports	5	5	5	5	5
P_{39} For. Proc. Exports	44	44	44	44	44
P_{40} H. & F. Exports	-	-	-	10	10
P_{41} Mining Exports	1	1	1	1	1
P_{42} P. P. P. Exports	451	636	636	636	636
P_{43} Other Mfg. Exports	212	212	212	212	212
P_{44} Imm. ('000)	19	320	322	346	357
P_{45} Imm. Cons.	19	288	257	173	-
P_{46} Total Cons.	4058	4331	4331	4341	4338
Total labour force	1140	1291	1292	1304	1310
Total Population	2988	3289	3291	3315	3326
Cons. /head ($)	1358	1317	1316	1310	1304

TABLE 6.4D

Effect of Lowering Immigrants' Consumption Requirements
(Shadow Prices)

Solution No.		1	16	17	18	19
Min. cons. ($mn/'000)		1.0	0.9	0.8	0.5	0.0
R_1	Farming	1.026	1.023	1.019	1.006	.984
R_2	Forestry	1.032	1.027	1.014	.975	.907
R_3	Forestry Proc.	.993	.990	.987	.978	.962
R_4	Hunt. & Fish.	1.447	1.434	1.389	1.591	1.382
R_5	Mining	1.121	1.118	1.120	1.125	1.134
R_6	P.P.P.	1.133	1.129	1.125	1.111	1.086
R_7	Other Mfg.	1.025	1.025	1.036	1.069	1.129
R_8	Bldg. & Const.	1.212	1.208	1.207	1.202	1.195
R_9	Publ. Ut.	2.184	2.186	2.230	2.360	2.591
R_{10}	Transp. & Comm.	1.330	1.327	1.332	1.346	1.371
R_{11}	Distribution	.965	.959	.937	.868	.749
R_{12}	Bank. & Ins.	.932	.930	.927	.914	.894
R_{13}	Services	1.388	1.396	1.354	1.224	.997
R_{14}	Serv. to H/hold.	.799	.787	.738	.587	.324
R_{15}	Serv. to Govt.	.799	.787	.738	.587	.324
R_{16}	Ownership (interind.)	2.221	2.216	2.209	2.187	2.152
R_{17}	Ownership(final dem.)	.484	.482	.476	.475	.424

TABLE 6.4E

Effect of Lowering Immigrants' Consumption Requirements
(Shadow Prices)

Solution No.	1	16	17	18	19
Min. cons. ($mn/'000)	1.0	0.9	0.8	0.5	0.0
R_{18} Farm. Cap.	.162	.162	.166	.176	.195
R_{19} Forest Cap.	.166	.166	.169	.180	.199
R_{20} For. Proc. Cap.	.180	.181	.185	.198	.221
R_{21} H. & F. Cap.	-	-	-	.175	.192
R_{22} Mining Cap.	.169	.169	.172	.180	.195
R_{23} P. P. P. Cap.	.170	.171	.177	.194	.224
R_{24} Other Mfg. Cap.	.174	.175	.180	.196	.224
R_{25} Bldg & Constr. Cap.	.163	.164	.170	.190	.225
R_{26} Publ. Util. Cap.	.171	.172	.177	.192	.220
R_{27} Trans. & Comm. Cap.	.170	.171	.178	.199	.236
R_{28} Distribution Cap.	.166	.166	.167	.170	.176
R_{29} Bank. & Ins. Cap.	.179	.179	.179	.182	.186
R_{30} Services Cap.	.093	.171	.175	.187	.208
R_{31} Govt. Inv. (autonomous)	1.186	1.184	1.189	1.203	1.228
R_{32} Ownership Cap.	.181	.181	.181	.181	.180
R_{33} Ownership Inv. (autonomous)	1.208	1.206	1.205	1.203	1.201

TABLE 6.4F

Effect of Lowering Immigrants' Consumption Requirements
(Shadow Prices)

Solution No.		1	16	17	18	19
Min. cons. ($mn/'000)		1.0	0.9	0.8	0.5	0.0
R_{34}	Foreign Exch.	1.141	1.164	1.304	1.731	2.480
R_{35}	Savings	-	-	-	-	-
R_{36}	Labour	2.782	2.741	2.570	2.045	1.129
R_{37}	Max. Farm. Exp.	.097	.123	.276	.708	1.480
R_{38}	Max. For. Exp.	.087	.114	.266	.731	1.545
R_{39}	Max. For. Proc. Exp.	.130	.155	.298	.735	1.502
R_{40}	Max. H. & F. Exp.	-	-	-	.199	1.125
R_{41}	Max. Mining Exp.	.010	.035	.174	.599	1.342
R_{42}	Max. P. P. P. Exp.	-	.026	.170	.613	1.387
R_{43}	Max. Oth. Mfg. Exp.	.099	.121	.252	.650	1.347
R_{44}	Min. Imm. Cons.	.931	.931	.937	.953	.981
R_{45}	Total Cons.	-	-	-	-	-

However, an examination of the shadow prices shows that as the level of income for immigrants is neglected there is a complete change in the policy priorities dictated by the model. There is a gradual reversal of the relative scarcities of foreign exchange and labour, and marked increases in the opportunity costs of the restrictions on exporting activities (Table 6.4F). It would be the same basic forces which cause the model to choose the consumption activity with 10 per cent import substitution (Table 6.4C) and the marginal productivities of capital to rise (Table 6.4E).

In short, failure to allow a reasonable level of consumption for immigrants will cause higher levels of immigration to be programmed and something will be sacrificed in terms of consumption per head. The overall level of activity in the economy will not change much, but the increased numbers of immigrants will put great pressure on the balance of payments while going some way towards relieving labour shortages. It would not be advisable, therefore, to abolish this part of the model unless the expansion of export markets or the improvement of prices is assured. This assurance could hardly be given confidently at the present time.

6.6 Capital Requirements for Immigrants

It was thought that the reluctance of the model to include large amounts of immigration might be due to the heavy capital requirements incorporated. Immigrants are likely to be more efficient users of capital than indigenous New Zealanders in that they are prepared to live in smaller houses, work longer hours and so forth. For this reason it was decided to reduce the housing capital requirements by 10 per cent and 20 per cent, but the effect on the optimum solution was negligible. The high surplus of savings has revealed investment to be of minor importance; it seems that the real bottleneck to development is foreign exchange and it is this which ultimately obstructs in inflow of immigrants - not through the direct import requirements, but through the increased strain on imports caused by higher levels of activity in the economy.

CHAPTER VII

LIMITATIONS OF THE STUDY

Any scientific or cultural study cannot be expected to be all-embracing; it can only be demanded that the best use be made of the time, skill and facilities available for the undertaking. While the methods employed in this study are potentially powerful, there are, as has been mentioned periodically throughout the text, a number of shortcomings, theoretical and applied. It is intended in this chapter to gether these thoughts together so that the study as a whole can be regarded in its true perspective.

7.1 Capital and Replacement of Capital

Organisation of the purchase and use of capital equipment is critical to economic development, but, unfortunately, effective measurement of capital is difficult. The capital stock values which have been used are obtained synthetically and any judgment as to whether these figures might understate the true technological capacities of the sectors could only be subjective. Thus the assumption that in the base year all sectors were operating at close to full capacity is made primarily for convenience. The capital-output ratios which link these "capital-stocks" to the rest of the model are also suspect, although it is probable that they give a reasonable representation of the relative differences in capital requirements between sectors. It seems then that little importance can be attached to the absolute values of investment programmed, but something might be gained from comparing investment levels of different solutions of the model and within the same solution.

A feature of capital which is frequently overlooked is that it is not generally substitutable between different processes. This has been acknowledged in the model to the extent that there is a separate, non-transferable capital stock for each sector, but the specialised nature of plant within sectors is probably no less important. Also, the embodiment of technological change in capital has been virtually ignored. Arbitrary reduction of the capital-output ratios has been demonstrated as a means of evaluating the importance of technological change, although more precise knowledge of the nature of such developments is needed before such analysis will become very useful. Is technological change in a particular industry likely to be labour saving (capital intensive) or capital saving (labour intensive)? Are the same input-output coefficients relevant when technological change has occurred? Such questions have not been answered and the resulting distortion of the numerical results may be serious.

The treatment of depreciation and capital replacement is another difficulty closely allied to the above discussion. Depreciation coefficients related to the level of output and based on accounting depreciation rather than statistics of actual capital replacement have been used - mainly because no others are readily available. These may be totally unrelated to patterns of capital replacement, which is what really affects resource requirements, which are the major concern of this study. Physical replacement of capital is certainly lumpy over time at the firm level, and it is hoped that in the aggregated sectors these "lumps" tend to level out due to different firms replacing capital at different times. Some sectors, however, are composed of only a few independent corporations, so that this assumption is dubious. Another consequence of the heterogeneity of capital stocks within a sector is that some capital goods have a longer economic life than others, and will need to be replaced less frequently. For instance, buildings will generally last much longer than machinery, so that the average annual inputs of capital goods for replacement will have a lower proportion of buildings and a higher proportion of machinery than the inputs of capital goods for net investment. This particular factor has been allowed for in the additions, representing replacement expenditure, that have been made to the current input-output coefficients: the additions are based on capital input-output coefficients but are weighted so that the inputs of "Building and Construction" capital goods constitute lower proportions of the totals; that is, a unit of replacement capital has a lower content of building than a unit of net investment capital.[1] This is little more than a palliative, however, as the durabilities of all types of capital vary considerably. Especially is this true of the rates at which equipment becomes obsolescent, which means that this problem is intertwined with that of measuring technological change.

7.2 Depth of Analysis

Although the model is designed to measure simultaneously the effects of the closely interrelated forces which affect overall economic activity, there are a number of very important factors which have not been incorporated.

Firstly, there is the question of the level of aggregation. The model does not yet treat the economy in a sufficiently detailed

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[1] See Appendix I.

manner to produce very conclusive results. It is very likely that some of the important interrelationships occur within some of the "cells" of the input-output matrix and thus escape scrutiny. There is no specific treatment of potentially lucrative industries such as tourism and the optimal structure may be biased because of this.[1] Nor is there any provision for classification of the labour force with limits on labour mobility. In general, however, there are few theoretical obstructions to these refinements being added to the model - the availability and accuracy of data are the main problems. As more detail becomes available the model can be quickly and easily modified to include it.

Secondly, the model over-simplifies the economic process and patterns of economic behaviour. Before economic projects can be initiated the financing arrangements have to be feasible; there are no constraints in the model to ensure this. It is left to the policy makers using the results of the model to consider the financial problems, but it would be more satisfactory if equations representing attitudes to borrowing and lending were part of the main analysis. Apart from financing, there are shortcomings in the model with respect to the operation of the market mechanism. In Chapter I there was some discussion of the inability of a laissez-faire economic system to pursue adequately the economic goals of society, and it was inferred that such a system could not exist in a pure form. However, this study assumes perfect competition and makes no attempt to allow for lags in price and quantity adjustment.

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[1] Tourism has been assumed to be an export of "Other Manufacturing". The high output programmed for this sector might be interpreted as favouring tourist promotion.

Thirdly, the interpretation of the numerical results has been a little apologetic. Not sufficient confidence is placed in the accuracy of the original specification to enable any but the most obvious conclusions to be made. The output levels programmed for the majority of sectors supply no more information to economic planners than do projection methods as no statistical tests can be applied to the optimal solution, because the stochastic characteristics of the base year data are unknown. Consequently, little can be said about the target for "Transport and Communication", for instance, other than that it is "about the same as the projected target" and is probably "about right"; the targets for most sectors give planners only a rough indication of what the economic structure in the future should be. In this sense, the study effectively analyses three or four rather than sixteen sectors.

7.3 Comparative Statistics

The model gives no indication of the dynamics of the optimum solution. It merely gives a comparison between the economic situation at two points in time. The value (-6.6667) of the coefficient relating target year investment flows to capital stocks was chosen as an approximation to a 4 to 5 per cent annual rate of growth of investment, but this same value would be appropriate for a large number of investment growth patterns (e.g. when the initial rate of growth is very low and later on in the period it is much higher). Likewise, the optimum time pattern of production is not revealed in the analysis. These are very important problems to economic planning bodies - the degree of choice is much larger over time.[1]

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[1] See Dorfman, Samuelson and Solow [10], Ch.14.

Consequently, a polyperiod linear programming model would be much more suitable as the analyst is able to account for the way in which the labour force, export limits, technology, etc., will change during the period; the temporal production and investment patterns required will, therefore, be one of the results of the computation. Such polyperiod models are very demanding on data and computer capacity, however. The present model is aimed at giving only a general indication to policy makers.

7.4 Prices

The whole analysis has been carried out in base year (1964-65) prices. There is no guarantee that when the price level changes the same input-output coefficients represent the character of the economy. The shadow prices of the linear programming solution indicate that there will be some pressure on the relative prices of different commodities as the solution is implemented. This also may invalidate the original coefficient values. Changes in parameters due to adjustments in the price level and in relative prices could mean that the "optimum" solution is, in fact, rather different from the true optimum. Allowing prices to vary would introduce non-linearities into the equations so that more sophisticated programming would be necessary.

7.5 Savings

The treatment of savings as a constant proportion of gross national product could be misleading. Apart from the problem of choosing the correct value for the ratio, there is a difficulty in that oscillations in the economic climate undoubtedly affect the community's preparedness to save. It is likely that the resultant short term fluctuations in investment patterns are, in fact, a bottleneck to the longer term development of the economy. The savings surplus which has resulted in this study could be fallacious. No attempt has been made to account for this possibility in the formulation of the model, and it is difficult to see how it would be achieved using linear programming. Polyperiod models would be useful as the pattern of investment required over time can be calculated, but other economic studies would still have to be carried out so that policy makers would know how these investment levels could be achieved.

7.6 Need for Current Data

The difficulty of obtaining up-to-date data is a factor which limits the usefulness of the model. The various theoretical objections to the use of input-output coefficients do not loom as large when they are based on recent interindustry transactions tables. The basic data for this study is for 1959-60 so the model contains parameters which are a decade out of date. Admittedly, the data has been updated to 1964-65 using the R.A.S. technique, but the accuracy of this has not been tested and it will not be possible to do so until more recent interindustry statistics are available. Even the use of 1964-65 as base year is unfortunate, as the planning horizon at the time of the analysis, was half completed. The more ways that can be found of speeding up the mechanics of putting the model together, the more use it will be for practical indicative planning.

7.7 Objectives of Policy

There was some discussion in Chapter I on the problems of formulating realistic objective functions. Maximisation of consumption with constraints on resource use, savings and the balance of payments, and the allowance of consumption for immigrants are reasonably satisfactory as far as long term policies are concerned; but there are no devices which prevent inequitable income distribution, regional disparities of resource use, or price instabilities. The planning committee must be able to consider such aspects of the programmed structure before policy decisions are made. The programmed solution does not account for social values although the consumption and capital requirements for immigrants should be regarded as steps in the right direction.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

8.1 Summary of Results

Bearing in mind the limitations which have been forwarded concerning this study, the following comments relating to the medium and long term economic development of New Zealand are warranted:

(1) Given that expansion of manufactured exports will be difficult, it is important that markets for primary products exported from New Zealand should be maintained and that investment in farming should continue at a high level so that the current high standard of living in New Zealand should not deteriorate. This policy should apply even when agricultural export prices are low. The economy is particularly sensitive to the loss of markets for processed primary products.

(2) Expansion of the economy and improvement in living standards are more dependent on the encouragement of new products and new industries than on traditional ones. In particular, serious efforts should be made to find further export markets for processed forestry products and for secondary manufactured goods.

(3) An intensive immigration policy would not be of immediate benefit to the economy. Additional labour is required, but it is only after export markets have expanded that the economy is likely to be able to stand the additional pressure on foreign exchange (as well as on other resources). At the same time a small amount of immigration is recommended. It stands to reason that, where possible, the immigrants admitted have skills in industries which have export potential.

(4) There should be some encouragement of import substitution industries which will significantly ease the balance of payments. This should not, however - at least on existing evidence - be a major policy priority.

8.2 Practical Use of the Model

This study has aimed only at demonstrating the methodology of using linear programming for national economic planning. The numerical results should be interpreted tentatively until the model is further disaggregated and, if possible, until more attention is given to price changes and the time pattern of production. However, the problem of out of date data is perhaps the most serious shortcoming. J.K. Galbraith's comment relating to industrial firms that "a bad decision made on time will not usually be as costly as a good decision made too late"[1] might equally apply, at least in part,

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[1] See Galbraith [15], p. 64.

to economic policy decisions. Data should be quickly processed and inserted in the model so that the exercise is concerned with the future rather than merely being useful for comparison with the present.

It would be easier to achieve this if the model was set up by a team of workers rather than a solitary researcher. Not only would this abbreviate the time taken to carry out the analysis, but it would enable each contributor to specialise in a particular aspect of the model without losing sight of the overall aims of the project. Thus the need for greater detail could be attended to without seriously neglecting the complicated network of interrelationships which is the key to this type of analysis. With this kind of approach it would be possible to work simultaneously towards the development of a polyperiod model.

It is envisaged that the use of this model should be a continuous operation. As more accurate data, or knowledge of changing circumstances, becomes available, policy decisions should be reconsidered in the light of the new optimum solution and its stability. There will inevitably be a lag between the solution of the model and the implementation of policy. If the optimum structure was revised (or rather, recalculated), for example, at two or three monthly intervals it could be possible to make last minute policy adjustments. There is also a chance that serious anomalies, or misinterpretations of earlier solutions will be exposed before their consequences are too far reaching.

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REFERENCES

[1] Baumol, W.J. : Economic Theory and Operations Analysis, Prentice Hall, 1961.

[2] Blyth, C.A. and Crothall, G.A. : A Pilot Programming Model of New Zealand Economic Development, Econometrica, Vol. 33, No. 2, April, 1965 : 357-381.

[3] Cameron, Burgess : Import Substitution, Economic Record, December, 1964 : 500-507.

[4] Cameron, Burgess : Input-Output Analysis and Resource Allocation, Cambridge University Press, 1968.

[5] Candler, W. and Hampton, P. : The Measurement of Industrial Protection in New Zealand, Australian Economic Papers, Vol. 5, No. 1, June 1966 : 47-58.

[6] Chenery, H.B. : The Role of Industrialisation in Development Programs, American Economic Review, XLV, No. 2, May, 1955 : 40-57.

[7] Chenery, H.B. : Development Policies and Programs, Economic Bulletin for Latin America, III, No. 1, March, 1958.

[8] Chenery, H.B. and Clark, P.G. : Interindustry Economics, Wiley, 1959.

[9] Chenery, H.B. and Kretschmer, S.K. : Resource Allocation for Economic Development, Econometrica, Vol. 24, No. 4, October, 1956 : 365-399.

[10] Dorfman, R., Samuelson, P.A., and Solow, R.M. : Linear Programming and Economic Analysis, McGraw Hill, 1958.

[11] Easton, B.H. : Consumption in New Zealand 1954-5 to 1964-5, New Zealand Institute of Economic Research, Research Paper No. 10, 1967.

[12] Fox, K.A., Sengupta, J.K., and Thorbecke, E. : "The Theory of Quantitative Economic Policy; with applications to economic growth and stabilisation", North Holland, 1966.

[13] Francis, T.W. : Sectoral Capital Formation in New Zealand 1958-65, Agricultural Economics Research Unit, Research Report No. 52, Lincoln College, 1968.

[14] Frisch, R. : Principles of Linear Programming, Universitetets Social ϕkonomiske Institutt, Oslo, 1954.

[15] Galbraith, J.K. : Economic Development in Perspective, Harvard University Press, 1962.

[16] Ghosh, A., : Planning Programming and Input-Output Models, Cambridge University Press, 1968.

[17] Hadley, G., : Linear Programming, Adison-Wesley, 1965.

[18] Hampton, P., : The Degree of Protection Accorded by Import Licensing to New Zealand Manufacturing Industry, Agricultural Economics Research Unit, Research Report No. 12, Lincoln College, 1965.

[19] Heady, E.O., and Candler, W. : Linear Programming Methods, Iowa State University Press, 1958.

[20] Lewis, W. Arthur : The Principles of Economic Planning, A study prepared for the Fabian Society, Geo. Allen and Unwin, 1949.

[21] Manne, A., : Key Sectors of the Mexican Economy 1960-70, Chapter 16 of Studies in Process Analysis, ed. by A. Manne and H.M. Markowitz, Cowles Commission Monograph 18, Wiley, 1963.

[22] Matuszewski, T.I., Pitts, P.R., and Sawyer, J.A. : Alternative Treatments of Imports in Input-Output Models : A Canadian Study, Journal of the Royal Statistical Society, Vol. 126, Part 3, 1963 : 410-432.

[23] Monetary and Economic Council : Increased Immigration and the New Zealand Economy, Monetary and Economic Council Report No. 12, 1966.

[24] Moustacchi, A., : The Interpretation of Shadow Prices in a Parametric Linear Economic Programme, Econometric Analysis for National Economic Planning, ed. by P.E. Hart, G. Mills and J.K. Whitaker, Butterworths, 1964 : 205-226.

[25] New Zealand Department of Statistics : Interindustry Study of the New Zealand Economy 1959-60, Parts 1 and 4, 1967.

[26] New Zealand Department of Statistics : Report on the Inter-industry Study of the New Zealand Economy for the Year 1954-55, 1959.

[27] New Zealand Yearbook.

[28] Philpott, B.P., and Ross, B.J., : Input-Output Models for Projecting and Planning the Economy, Agricultural Economics Research Unit, Research Report No. 41, 1968.

[29] Philpott, B.P., and Ross, B.J., : The Shape of the New Zealand Economy in 1979, New Zealand Economic Papers, Vol. 3, No. 1, 1969.

[30] Ross, B.J., and Philpott, B.P., : Indicative Economic Planning with a Sixteen Sector Projection Model of the New Zealand Economy, Australian Economic Papers, June, 1970.

[31] Ross, B.J., and Philpott, B.P., : Interindustry Structure of the New Zealand Economy 1961-5, Agricultural Economics Research Unit, Research Report No. 49, Lincoln College, 1968.

[32] Sengupta, J.K. and Fox, K.A. : Optimisation Techniques in Quantitative Economic Models, North Holland, 1969.

[33] Sewell, D.O. : Electric Household Durable Goods : Economic Aspects of their Manufacture in New Zealand, New Zealand Institute of Economic Research, Research Paper No. 8, 1965.

[34] Steering Committee : Report to National Development Conference, May, 1969.

[35] Targets Committee : Report to National Development Conference, May, 1969.

[36] Tinbergen, J., : Central Planning, Studies in Comparative Economics 4, Yale University Press, 1964.

[37] Tinbergen, J., : Economic Policy : Principles and Design, North Holland, 1956.

[38] Tinbergen, J., : On the Theory of Economic Policy, Contributions to Economic Analysis I, North Holland, 1952.

[39] Tinbergen, J., : The Design of Development, John Hopkins Press, 1958.

[40] Tinbergen, J., and Bos, H.C. : Mathematical Models of Economic Growth, McGraw Hill, 1962.

APPENDIX I

DEFINITION OF SIXTEEN SECTORS AND COMPILATION OF DATA

The sixteen sectors on which the results of this study are based are:-

(1) Farming: This sector encompasses the whole of farming in New Zealand : livestock, cropping, horticultural produce, poultry and agricultural contracting.

(2) Forestry and Logging: The establishment, maintenance and harvesting of trees.

(3) Forest Processing: The processing of raw timber into sawn timber and other building materials or fittings, and the processing of raw timber into pulp and paper products.

(4) Hunting and Fishing: The production of raw fish, and pest extermination and acclimatisation activities.

(5) Mining: Mainly composed of coal production and limestone production.

(6) Primary Produce Processing: The production of frozen and preserved meat, the production of butter, cheese and other dairy products, and the freezing and preserving of fruit and vegetables.

(8) Building and Construction: All building construction and the construction of civil engineering structures and roads; building repair.

(9) Public Utilities: The production of electricity and gas, and the provision of water and sanitation.

(10) Transport and Communication: All forms of land, sea or air transport activities plus the activity of the New Zealand Post Office (excluding the Post Office Savings Bank).

(11) Wholesale and Retail Trade: The activity of establishments responsible for the distribution of goods produced elsewhere; the output is valued not at the retail value of the goods handled, but at the wholesale to retail margin; this is considered to be the value of the service of distribution.

(12) Banking and Insurance: Banks, insurance companies and other financial organisations.

(13) Services: Education, medical, legal, accounting services, and all forms of professional or technical advice; restaurant and accommodation services; personal and miscellaneous services such as undertaking, dry-cleaning, carpet laying, etc.

(14) Services to Households: Services in which wages are paid directly to the labour involved by private consumers (servants, household help) or by non-profit organisations (paid secretaries of sporting clubs).

(15) Services to Government: Wages paid by the government and other public authorities for administrative activities or for the maintenance of law and order.

(16) Ownership of Property: All imputed and real landlord activity; the value of output is the imputed rental value of owner-occupied houses plus the actual rental value of non-owner-occupied houses and business premises.

The coefficients for the current production activities were derived from Table VII, page 52, Ross and Philpott[31]. These coefficients have been adjusted to account for extra output that will be required to replace obsolete and worn-out capital equipment.

The adjustments were in the form of additions to the current intermediate coefficients and import coefficients. The sum of the additions for each current production activity were equal to the depreciation coefficient (derived from interindustry tables) for that activity. This total was distributed among the inputs for the activity using the proportions suggested by the capital input-output matrix, but the proportions were weighted against inputs from "Building and Construction" by a factor of five. This was an attempt to account for the fact that building is more durable than plant and machinery, and that the average unit of replacement expenditure in any year will include a lower proportion of expenditure on buildings than a unit of net investment expenditure in the same sector. The weight 1/5 was used as a likely approximation to the ratio of the rate at which buildings depreciate with respect to plant and machinery: buildings can be expected to depreciate at 2-2½ per cent whereas plant and machinery is likely to depreciate at 10 per cent or more.

The capital-output ratios, the capital coefficients, and the labour-output ratios are the same as those used by Ross and Philpott [30] and their values were obtained by private communication with Professor B.J. Ross. The labour-output ratios have been adjusted for the expected productivity rise by 1972-73. The capital-output ratios are really <u>incremental</u> capital-output ratios; the assumption is made that average capital requirements of all sectors are the same as capital requirements at the margin.

The reason for the values of -6.6667 connecting the final year investment flows to the final year capital stocks have been given in Chapter IV, Sec. 4.4 and Chapter III, Sec. 3.4. Table 1a shows a series of values for the proportion of total investment in an eight year period which will occur in the final year at a number of annual growth rates in the level of investment. The calculations are similar to those used by Manne [21] and described in Chapter III, Sec. 3.4. From this table it is seen that if the annual growth rate in investment is around four or five per cent, approximately .15 of the investment during an eight year period will occur in the final year. This means that total capital formation during an eight year period will be 1 ÷ .15 or 6.6667 times the level of investment in the final year.

The coefficients for the consumption activities are calculated from the 1964-65 interindustry statistics [31], the import saving alternatives being calculated in the manner described in Chapter II. The immigrants' consumption activity has the same coefficients, but the coefficient for services to government is omitted on the grounds that there is not likely to be a large direct increase in the level of administration due to immigrants; the extra organisation required should be indirectly accounted for by the capital requirements of immigration.

TABLE Ia

Fraction of Investment Occurring in Final Year of Eight Year Horizon assuming Constant Annual Rate of Growth

Annual Growth Rate,	3%	4%	5%	6%
$(1 + g)^8$	1.2668	1.3686	1.4775	1.5938
$g(1 + g)^8$	.0380	.0547	.0739	.0956
$[(1 + g)^8 - 1]$	.2668	.3686	.4775	.5938
Proportion in final year	.1424	.1484	.1548	.1610

The capital requirements for immigrants are calculated from the estimated needs of immigrants for social capital suggested in the Monetary and Economic Council Report Number 12 [23]. The coefficient of -0.5000 is due to an assumption that every 1000 immigrants results in an addition of 500 to the labour force. This is a rounded off estimate of the figure published in the Monetary and Economic Council Report.

The capital stock availability figures are obtained artificially. It is assumed that in the base year, 1964-65, all sectors of the economy are operating at the full capacity of their capital stock. An artificial figure for "capital stock" can therefore be obtained by dividing the capital-output ratio into the base year level of output for each sector. This was done for all sectors except "Ownership of Property", a sector in which most of the investment has to be decided upon independently. However, some investment must occur within the model to allow for the building of premises to be leased or rented to the productive sectors; it was estimated how much of the 1964-65 output was of this nature, and the same proportion of the total "capital stock" for the sector was used.

The maximum overseas deficit for the target year, 1972-73, was chosen as $60 million in line with that suggested in the Targets Committee Report of the National Development Conference [35], page 11.

The labour force availability was calculated from the labour force projections published in the New Zealand Year Book Since these are published for calendar years, the figure used is a weighted average of the figures published for 1972 and 1973. The projection assuming zero net immigration was used as immigration is endogenous to this model.

The upper limits to the levels of the exporting activities were varied considerably for different solutions of the model, but their values were based on the export requirements computed by the Lincoln projection model. These, in turn, were in line with studies made by the sectoral working committees set up by the National Development Conference.

APPENDIX II

NOTES ON COMPUTATIONAL ASPECTS OF THE LINEAR PROGRAMMING PROBLEM

The problem was solved on the IBM 1130 computing system at Lincoln College using the IBM Linear Programming System/1130, QMOSS, Program Number 5711-CØ1. Some difficulty was experienced in obtaining a satisfactory solution printout due to a fault in the routine, and communication with IBM was necessary to resolve the problem. Previous to this it had only been possible to obtain a satisfactory printout of the shadow prices or dual solution, and the solution values for the primal problem could only be obtained by setting the model up as the dual problem; the shadow prices of the dual problem are the primal solution values.

It has been stated in the text that economic alternatives in the model are few. This does not mean that the computational alternatives are also few - in fact they are rather many. The objective to the problem is a function of consunption only so that it is only after enough iterations have taken place for a consumption activity to be included in the basis that the objective function has any value at all; as consumption requires inputs from each of the productive sectors it cannot be activated unless each of the productive sectors is activated.

The QMØSS routine has an option which enables advanced starting solutions to be used. It was found that the computation time could be drastically reduced by inserting a basis with all the production and investment activities included. This would be worthwhile even if several technological alternatives were available - the large number of iterations needed before consumption can enter the basis would be avoided.

APPENDIX III

ASSUMPTIONS UNDERLYING PRINCIPAL LINEAR PROGRAMMING SOLUTION

The main assumptions embodied in the principal linear programming solution discussed in this study (Solution No. 1, Tables 5.1A to 5.1F) are listed here for easy reference.

(1) That the constant-price current input-output coefficients calculated for 1964-65 would still be valid in 1972-73.

(2) That labour productivities would increase during the planning horizon at the rate assumed by Ross and Philpott [30] in their projection study.

(3) That import substitution of intermediate goods would not occur, but that import substitution of finished goods was possible.

(4) That the capital-output ratios calculated from historical data and the constant-price capital input-output coefficients for 1964-65 would continue to be relevant in the target year.

(5) That the population and labour force would increase at the rate projected by the Department of Statistics (assuming zero net migration) unless immigration occurs.

(6) That at least $1 million of consumption goods (1964-65 prices) be set aside for each 1000 immigrants.

(7) That the maximum level of exporting in each sector in 1972-73 will be the same as the levels of exporting projected by Ross and Philpott [30]. * (See Note overleaf.)

(8) That export prices in 1972-73 will be the same as in 1964-65 for all products.

(9) That total gross domestic savings will be 28 per cent of gross national product.

(10) That in 1972-73 the level of investment in housing will be at least $225 million and that the level of autonomous government investment will be $228 million (both values in 1964-65 constant prices).

Of these assumptions, numbers (1), (2), (4), (7) and (10) are comparable to assumptions made by Ross and Philpott [30] in the Lincoln projection model. The greater flexibility of the linear programming technique has meant that fixed assumptions regarding import substitution, population and labour force were not necessary. The major difference between the two studies was with respect to export prices. In the projection model an overall decline of 5 per cent was assumed whereas no decline was allowed for in the optimising model.

* Note: Exports are handled differently in the linear programming model in that the contributions of services are treated as margins rather than as actual exports from the servicing sectors (see Chapter III, page 44). One of the consequences of this has been that the export returns from tourism which appear in the interindustry tables as output from "Transport & Communication" have been allocated to "Other Manufacturing". This accounts for the large differences between exports from "Other Manufacturing" in Tables 5.4 and 5.5.

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